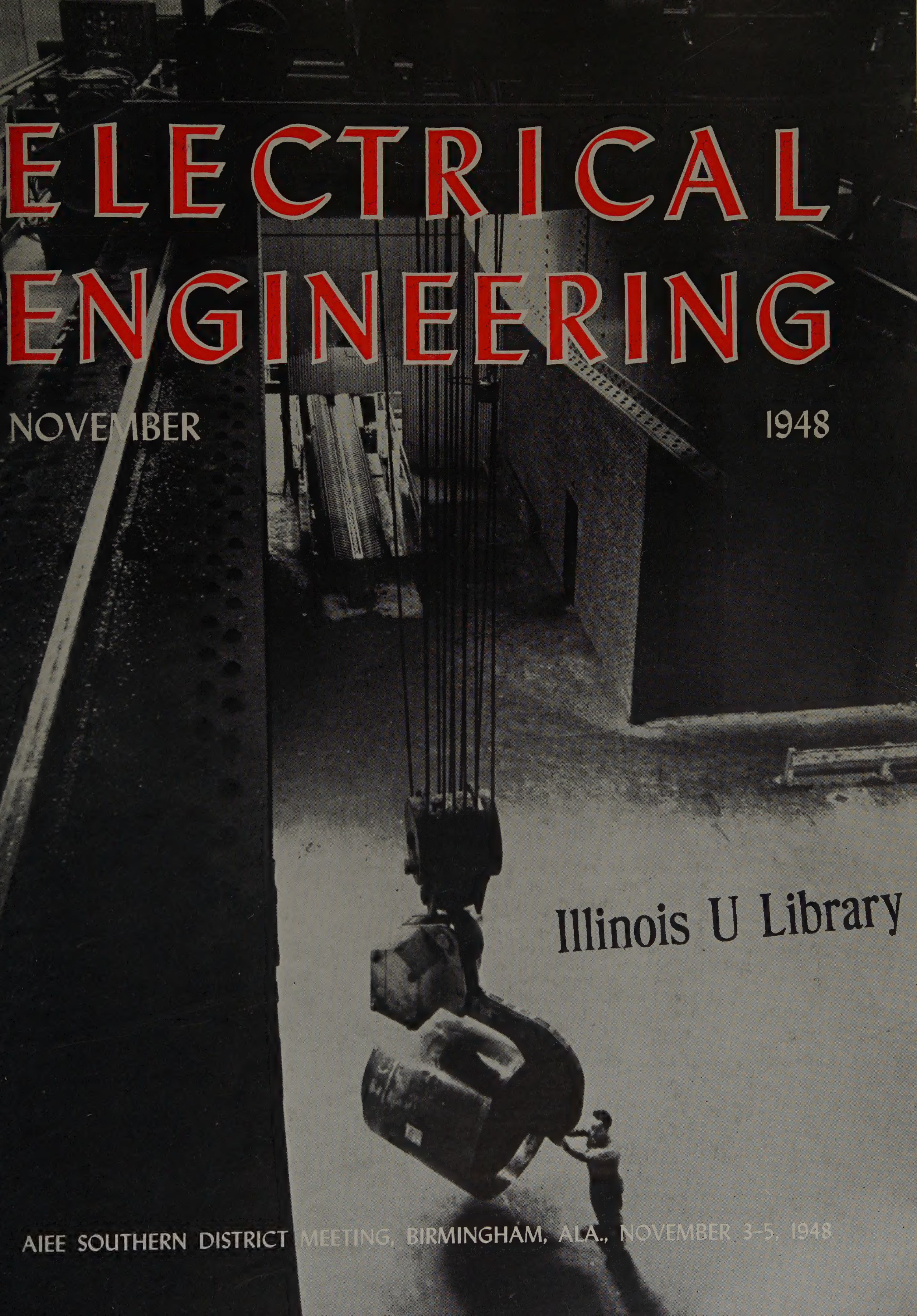
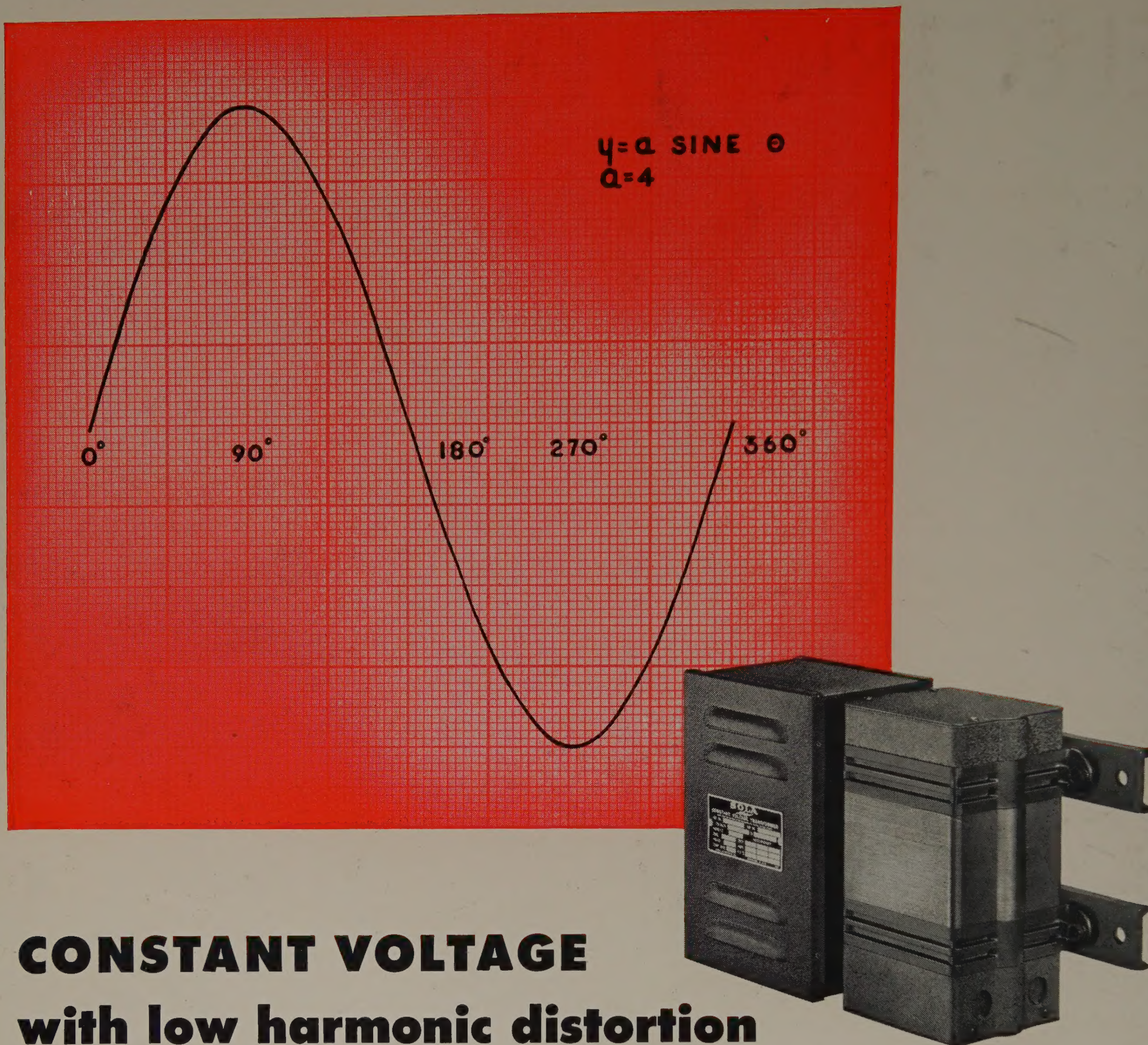
ELECTRICAL ENGINEERING

NOVEMBER 1948



AIEE SOUTHERN DISTRICT MEETING, BIRMINGHAM, ALA., NOVEMBER 3–5, 1948



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ELECTRICAL ENGINEERING

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NOVEMBER 1948

The Cover: Three-ton coil being transferred from pickling line conveyer to tandem mill conveyer, visible in background, in 56-inch cold mill of a steel company. A 100-horsepower mill-type motor drives the main hoist of this 40-ton crane.

Westinghouse photo

Origin of the Electric Motor .... Joseph C. Michalowicz . . . 1035
Steady-State Analysis of D-C Generators . Ernest Van Valkenburg, Whitney Matthews . . . 1041
Inductive Co-ordination in Rural Areas .... M. W. Rothpletz, H. S. Williams . . . 1042
Diode Circuit Analysis .... R. H. Dishington . . . 1043
Protection of the Airplane Main Bus .... D. W. Exner . . . 1050
The Copper Oxide Rectifier 1051
Polarized Relay as Aircraft Control Element . . . Royce E. Johnson, Frank A. Glassow . . . 1059
Line-Fault Locator Using Fault-Generated Surges . . R. F. Stevens, T. W. Stringfield . . . 1060
Mathematics for Engineers—II .... H. Poritsky . . . 1061
A 6-Trace Cathode-Ray Oscillograph .... P. L. Edwards . . . 1064
13,800-Volt Distribution in the Bunker Hill Mine .... LeVern M. Griffith . . . 1065
Liquid Dielectrics for Transformers .... J. G. Ford . . . 1066
True Dielectric Breakdown Strength of Cable Papers ..... Paul Cloke, Burt Bates . . . 1072
Electrostatic D-C Transformer .... José Mireles Malpica . . . 1074
Principles of Protective Relaying .... E. L. Harder, W. E. Marter . . . 1075
An Automatic Standing Wave Indicator .... Philip J. Allen . . . 1082
Carbon-Pile Voltage Regulator Improvements .... B. O. Austin, H. H. C. Richards . . . 1083
Effects of Silicone Vapor on Brush Wear .... J. Marsden, Robert H. Savage . . . 1084
Simplified Calculation of Fault Currents .... An AIEE Committee Report . . . 1085
Electric Power Distribution Systems .... An AIEE Committee Report . . . 1088
Pacific General Meeting Conference Paper Digests 1104

Miscellaneous Short Items:
New Shunt and Inductor Designs, 1040; Creep Measurement With Wire Gauges, 1049; Standards of Very Small Capacitance, 1063; Plastics Protect Antennas, 1071; Electrical Essay, 1073; Plastics Testing Machine, 1081; Dry Plating Process, 1103

Institute Activities . . . 1106
Of Current Interest . . . 1121

Statements and opinions given in articles and papers appearing in *ELECTRICAL ENGINEERING* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.

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HIGHLIGHTS . . . .

President's Message. "The program of the Section should offer the opportunity for each member to make himself a better electrical engineer—a better engineer." This month AIEE President Lee takes as the subject of his message to the membership, "The Sections of Our Institute, the Engineer and Continued Education" (*page 1106*).

Winter General Meeting. A technical program which will include 29 technical sessions and 6 conferences is planned for the 1949 winter general meeting. The meeting will be held during the week of January 31 at the Pennsylvania Hotel, New York, N. Y., a departure from the Institute's usual practice of holding this meeting at the Engineering Societies Building (*page 1107*).

Pacific Meeting Conference Papers. Authors' digests of most of the conference papers which were presented at the Pacific general meeting, Spokane, Wash., August 24–27, indicate the substance of these papers which are not scheduled for publication in AIEE *PROCEEDINGS* or AIEE *TRANSACTIONS* (*pages 1104–05*).

Section and Branch Activities. The AIEE's 81 Sections, 111 technical groups, and 41 Subsections held a total of 1,462 meetings during the year ending April 20, 1948, while 1,233 meetings were held by the Institute's 127 Branches during that same period, according to the annual report on Section and Branch activities for 1947–48 (*pages 1117–20*).

AIEE Conferences. On the agenda for the near future are three more in the series of conferences which have been attracting such interested attention. A complete program is announced for the first of these, a joint AIEE-IRE conference on electronic instrumentation in nucleonics and medicine to be held November 29–December 1, in the Engineering Societies Building, New York, N. Y. (*pages 1107–08*). The tentative technical program also is announced for the AIEE conference on electric welding. This conference will take place in Detroit, Mich., December 6–8 (*page 1109*). In January 1949, an AIEE conference on high-frequency measurements will be held at the National Bureau of Standards in Washington, D. C. (*page 1124*).

Electrical Essay. A problem entitled, "4-Terminal Network," appears in this issue as the latest in the series of electrical essays presented for the recreation of the reader. Also included is the answer to last month's essay (*page 1073*).

Digests. Most of the digests appearing in this issue of *ELECTRICAL ENGINEERING* are for papers which were presented at the Middle Eastern District meeting in Washington, D. C., October 5–7, 1948. Also included, however, is one remaining digest from the summer general meeting in Mexico, and two from the Pacific general meeting in Spokane, Wash., in August (*pages 1041, 1042, 1050, 1059, 1060, 1064, 1065, 1072, 1074, 1082, 1083, 1084*).

New Section Chairmen. A number of the Section chairmen who will preside during 1948–49 were introduced to the membership by photograph in the October issue. Others appear in the present issue (*pages 1110–11*).

Origin of the Electric Motor. In 1891 a series of articles by Franklin Leonard Pope proved that Thomas Davenport was the sole inventor of the electric motor. Again an effort is being made, by the author of this article, to pay tribute to this early American inventor (*pages 1035–40*).

Copper Oxide Rectifier. The history of the growth of the copper oxide rectifier illustrates how the by-product of an investigation may eclipse the original problem. The properties of the junction between copper and copper oxide were found incidental to attempts to construct relays without moving parts (*pages 1051–8*).

Protective Relaying. The basic principles of a number of different types of relay elements used in protective relaying schemes have been assembled in a convenient pictorial form which correlates simplified schematic diagrams of the elements with the operating characteristics. The AIEE long has been active in relay development through the work of its relay committee, which has maintained an up-to-date bibliography of papers and reports as a source of information (*pages 1075–81*).

Mathematics for Engineers. Continuing a series, the second article considers the selection of significant variables in engineering investigations and laboratory experiments. Under the assumption of partial linearity, it is possible not only to pick out a significant variable, but also to obtain coefficients of variation and the optimum value of the dependent variable (*pages 1061–3*).

Fault Current Calculation. A report on a simplified procedure for the calculation of fault current, originally presented to the Institute in 1942 by the AIEE committee on protective devices, is revised and brought up to date in this issue (*pages 1085–7*).

Diode Analysis. By considering the diode as a nonlinear circuit element and finding a system for analyzing the nonlinear current pulse resulting, a simple basic method has been devised which applies not only to diodes but to other similarly nonlinear devices. Examples are given of actual calculations on rectifier circuits (*pages 1043–9*).

Liquid Dielectrics. The liquid dielectrics known as askarels overcome the fire hazard of hydrocarbon oils, and although they do not possess all the good qualities of the oils, nevertheless are also suitable for transformer applications (*pages 1066–71*).

Distribution System Practices. A report by the AIEE distribution subcommittee of the transmission and distribution committee analyzes distribution system practices in the United States and points out the main reasons for these practices. The report is divided into three parts: Subtransmission circuits and distribution substations; the primary system from the substation bus to the distribution transformers; and the secondary or utilization voltage system from the distribution transformer to the service entrance (*pages 1088–1103*).

Correction. By error, a cut showing an aerial view of Grand Coulee dam and power plants, with the 230-kv left switchyard in the right background, appeared as Figure 1 of "The 230-Kv Ring Bus for Grand Coulee Power Plant," by N. G. Holmdahl and C. L. Killgore (*EE, Oct '48, p 967*). The figure should have shown, as indicated by the caption and the text reference, a 10-million-kva 3-cycle 20-cycle-reclosing conventional tank-type 230-kv oil circuit breaker.

News Index

Institute Activities **1106**

Message From President Lee 1106
Conference on Electronic Instrumentation 1107
AIEE *PROCEEDINGS* (how to order) 1107
Future AIEE Meetings 1107
Conference on Electric Welding 1109
New Section Chairmen (partial listing) 1110
Personal Notes 1112
Obituary 1115
Membership 1116
Section and Branch Activities Report 1118

Of Current Interest **1121**

Mathematical Society Hears Addresses 1121
Future Meetings of Other Societies 1125
Letters to the Editor 1125
New Books 1132
Pamphlets 1134

Industrial Notes **16A**

Trade Literature **25A**

New Products **36A**

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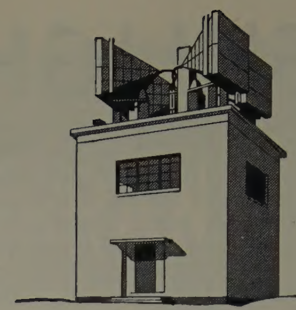
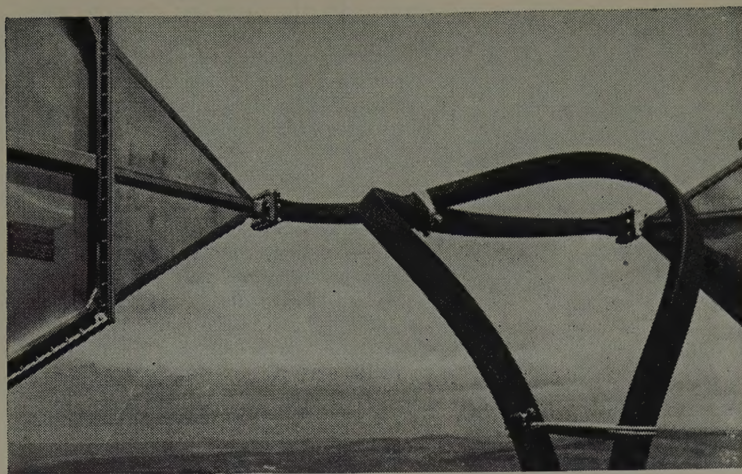
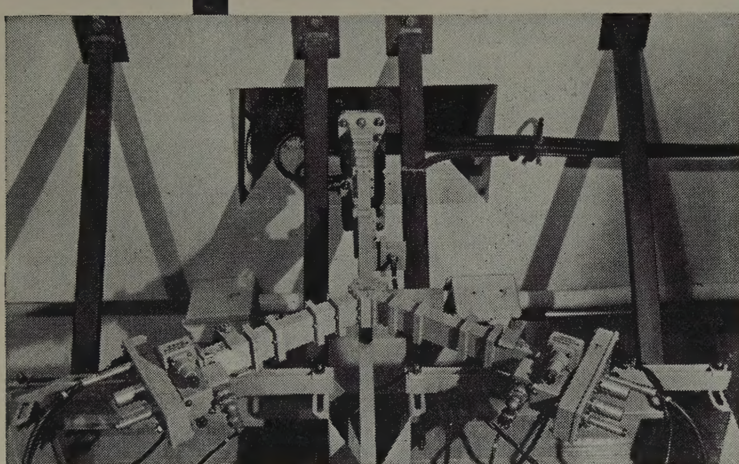


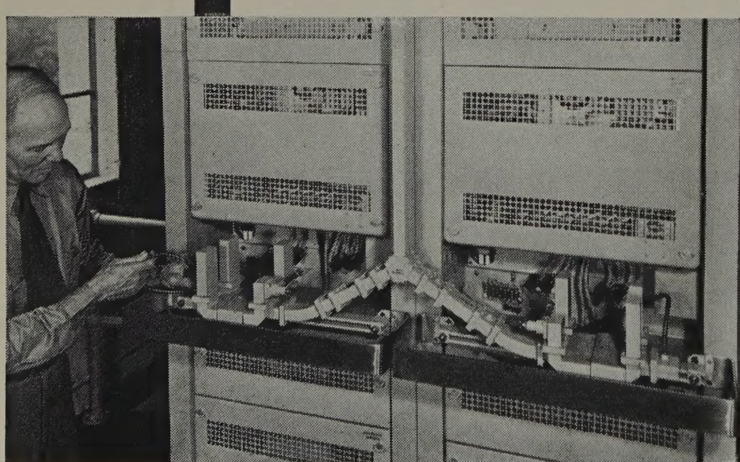
Pipe Circuits



3 The waveguide connects with horn antennas which are pointed toward similar antennas at the next stations miles away.



2 Looking upward, the waveguide continues through the roof of the station toward the antennas.



1 Base of a waveguide circuit in a repeater station of the New York-Boston radio relay system.

UNLIKE radio broadcast waves, microwaves are too short to be handled effectively in wire circuits. So, for carrying microwaves to and from antennas, Bell Laboratories scientists have developed circuits in "pipes," or waveguides.

Although the waves travel in the space within the waveguide, still they are influenced by characteristics found also in wire circuits, such as capacitance and inductance. The screw or stud projecting inside the guide wall acts like a capacitor; a rod across the inside, like an inductance coil. Thus transformers, wave filters, resonant circuits — all have their counterpart in waveguide fittings. Such fittings, together with the connection sections of waveguide, constitute a waveguide circuit.

From Bell Laboratories research came the waveguide circuits which carry radio waves between apparatus and antennas of the New York-Boston radio relay system. The aim is to transmit wide frequency bands with high efficiency — band widths which some day can be expanded to carry thousands of telephone conversations and many television pictures.

Practical aspects of waveguides were demonstrated by Bell Telephone Laboratories back in 1932. Steady exploration in new fields, years ahead of commercial use, continues to keep your telephone system the most advanced in the world.

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Origin of the Electric Motor

JOSEPH C. MICHALOWICZ
MEMBER AIEE

Had it not been for the efforts of men like Davenport, De Jacobi, and Page, the benefits of the electric motor would not be enjoyed today. It is the purpose of this article to trace briefly the early history of the science of electromotion and, in particular, to bring to light and to honor the inventor of the electric motor.

THE DAY that man molded the first wheel from the sledlike skids of his primitive wagon should be one of great commemoration, had not its identity been lost in the passing of time. Not unlike the wheel and probably second only to the wheel, the electric motor has been a great benefactor to man and its history, too, slowly is being forgotten.

Today, we hear very little, if anything, about Thomas Davenport, the blacksmith who invented the electric motor; or about De Jacobi, who propelled the first boat by means of an electric motor; or of Charles Page who successfully carried passengers on the first practical electric railway. Had it not been for the efforts of these men and others like them, the benefits of the electric motor probably would not be enjoyed today. It is the purpose of this article, in general, to trace briefly the early history of the science of electromotion and, in particular, to bring to light and to honor the inventor of the electric motor.

EARLY HISTORY

The development and rapid growth of our electrical science and the electrical industry can be followed very easily through the growth of the basic principles. The basic principle governing the operation of the electric motor is, of course, that of the production of motion by the use of magnetic fields. Legend tells us that the first exercise of this knowledge probably is accredited to Hoang Ti, the mythical founder of the Chinese empire, who was the first to construct a magnetic compass in 2634 B.C. Factually, the citation delivered by Andre-Marie Ampere in 1820 A.D. of the nature of the electric current and its relation to magnetism was the classic truth that was necessary for the development of the practical motor. Not quite a year later, Michael Faraday, using this information, produced rotation of a wire carrying electric current, around a magnetic pole. But it was not either of these two illustrious men who deserve credit for the development of the practical electric motor. There were others, some talented, some not, some prophetic, some curious, who, through discouragements and failures, were directly responsible for giving us the modern electric motor. Briefly, these early achievements, up to the year 1850, may be listed as shown in the following.

Essentially full text of paper **48-232**, "Origin of the Electric Motor," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

Joseph C. Michalowicz is assistant professor of electrical engineering, The Catholic University of America, Washington, D. C.

1821—Michael Faraday demonstrated for the first time the possibility of motion by electromagnetic means with the movement of a magnetic needle in a field of force.

1829—Joseph Henry, a teacher of physics at the Albany Academy in New York, constructed an electromagnetic oscillating motor but considered it only a "philosophical toy."

1833—Joseph Saxton, an American inventor, exhibited a magneto-electric machine before the British Association for the Advancement of Science.

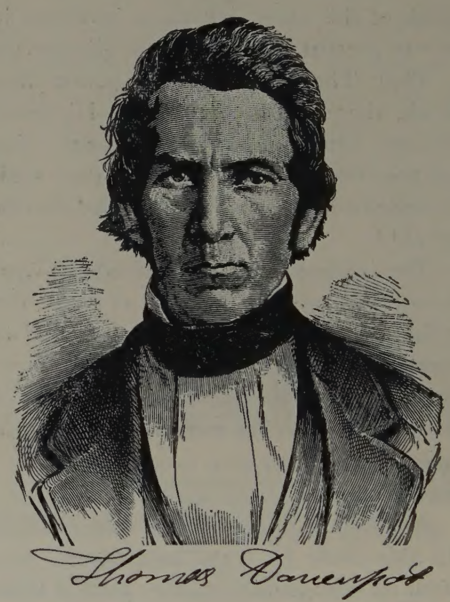


Figure 1. Thomas Davenport, inventor of the electric motor

Courtesy Smithsonian Institution

1837—Thomas Davenport, an American inventor, obtained the first patent on an electric motor.

1838—Solomon Stimpson, an American, built an electric motor having 12 poles and a segmental commutator.

1839—Moritz-Hermann De Jacobi, a Russian scientist, demonstrated the use of the electric motor to propel boats.

1840—Truman Cook, an American, built an electric motor having a permanent magnet armature.

1840—Robert Davidson, a Scot, built a lathe and a small locomotive powered by electric motors.

1845—M. Froment, a Frenchman, built an electric motor similar to a "breast wheel, whose paddles were acted upon by magnetism instead of water."

1847—Moses G. Farmer, an American, constructed and exhibited a 2-passenger car and locomotive driven by an electric motor.

1850—John Lillie, an American, constructed an electric motor having radially arranged permanent horseshoe magnets.

1850—Charles G. Page, an American, developed a solenoid-type electric motor.

Although these accomplishments and the many others that took place in the years following 1850, helped considerably in the design of our present electric motor, the most outstanding efforts were those of Davenport, De Jacobi, and Page. These are significant because Davenport's machine was, without a doubt, the first practical electric motor; De Jacobi's apparatus demonstrated the first practical application; and the device of Page showed the possibilities of a different motor design.

THE DAVENPORT MOTOR

Thomas Davenport, the rightful inventor of the electric motor, spent a life that seems more fictional than factual. His rigid understanding of the motor's principles, his clear vision of the possibilities of such a device, and his driving persistence to establish a foundation for a discovery too early for its time, easily should qualify him as a member in the society of Ampere, Faraday, Morse, Bell, and other immortals of the electrical science. To understand the trials of this early American inventor, it would be unwise not to present at least a slight glimpse into his early life.

That Thomas Davenport came from true American stock, there can be no doubt. His ancestors came to Dorchester, Mass., prior to 1640, a short time after the landing of the Pilgrims. His grandfather was a soldier in the American Revolution and he had two brothers in the War of 1812.

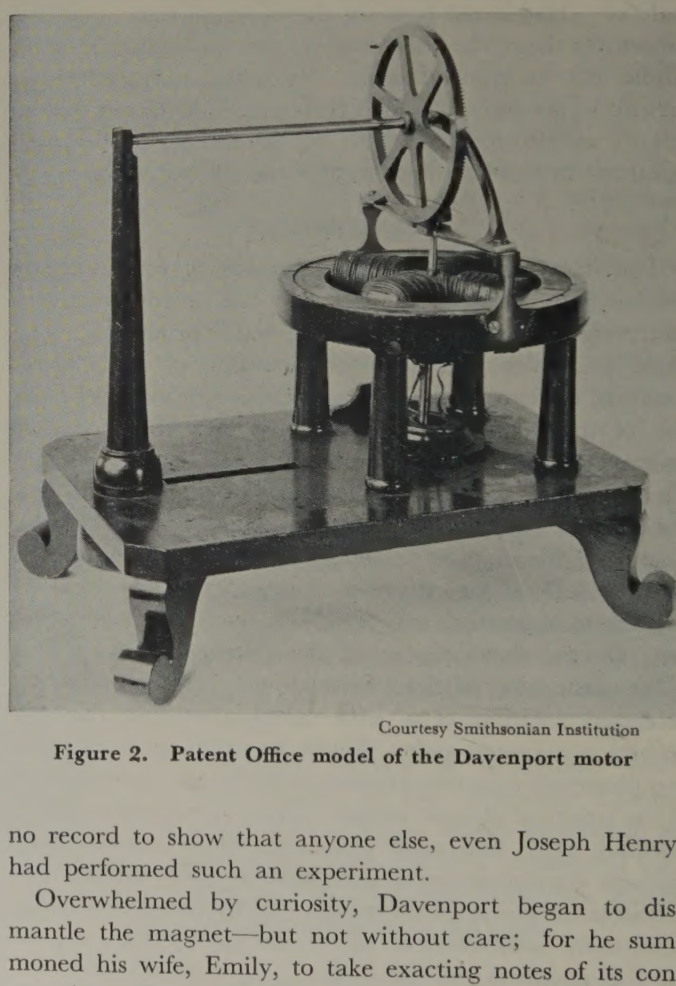
The inventor, one of 12 children, was born in Williamstown, Vt., on July 9, 1802, of poor, though patriotic and religious parents. His early boyhood consisted mainly of working the soil and tending the farm, but he did not neglect to obtain the little education that was available in those days. He took advantage of every possible moment in the classroom, even engaging in reading during the recess periods.

At 14 years of age, he became a blacksmith's apprentice. In this trade he was "bound out" for seven long years, with no compensation other than a knowledge of smithing and a 6-week term a year at school. Here again, he occupied his leisure time in reading books that he obtained from "auction" libraries.

At the end of his apprenticeship, though penniless, he started his own blacksmith's shop in the town of Brandon, Vt. He continued his trade for ten years until the year 1833 when his curiosity was aroused by a report that "a galvanic battery" which would "lift a common blacksmith's anvil" was on exhibition at Crown Point, N. Y. He instantly made the trip to Crown Point but was unable to view the device. Later reports informed him that this newly found wonder contained a horseshoe-shaped magnet. These accidental references of "anvil" and "horseshoe" had excited him so thoroughly, that he made plans for a second trip to Crown Point. Not having the funds with which to finance this second journey, he persuaded his brother Oliver, a "tin peddler," to take him in his peddler's cart.

Arriving at Crown Point, Davenport succeeded in viewing the "galvanic battery" which would "suspend an anvil between heaven and earth." It was an electromagnet invented a few years previously by Professor Joseph Henry of Princeton University. It consisted of a suspended horseshoe magnet about a foot long, wound with silk-insulated copper wire connected to a galvanic cell. It had been purchased by the proprietor of the Penfield Iron Works to separate the iron from the waste in the local low-grade ore. Davenport marvelled at the ability of this 3-pound magnet to raise an anvil weighing 150 pounds and, imagining that this power could be put to more useful work, asked its purchase price. The price was $75. Again brother Oliver was called upon. Reluctantly, Oliver traded his wares, his cart, and his horse for the necessary $75 plus a worthless nag, and the magnet was purchased.

Having brought the magnet home, Davenport discovered that he could make the magnet lose its power by disconnecting one of the wires to the battery and could restore it again by holding the severed ends together. This simple electrical fact immediately convinced him that the power bestowed upon the magnet was controllable. The starting and stopping of an electric current by the making and breaking of an electric circuit revealed a most important fact, the discovery of which, simple though it may seem today, well could be accredited to Davenport, for there is no record to show that anyone else, even Joseph Henry, had performed such an experiment.



Courtesy Smithsonian Institution

Figure 2. Patent Office model of the Davenport motor

Overwhelmed by curiosity, Davenport began to dismantle the magnet—but not without care; for he summoned his wife, Emily, to take exacting notes of its construction. From these notes, he constructed a larger magnet, using the silk from his wife's wedding dress as an insulator between the conductors. The home-made replica was a success. He built more and larger ones and predicted that "steamboats would be propelled by this power"

and that "it would replace the murderous power of steam."

Davenport's next objective was to convert the linear motion of the electromagnet into rotational motion and thereby make the flow of energy continuous. After much experimentation, he finally obtained rotational motion early in 1834. He accomplished this by mounting a magnetized iron bar horizontally on a bearing and held the electromagnet in such a position that its repulsion set the iron bar in motion. Then, by breaking the circuit by hand at properly timed intervals, he found that the iron bar could be kept in continuous motion.

Later, he built a better and larger motor, about which Davenport writes in his own memoirs:

> In July 1834, I succeeded in moving a wheel about seven inches in diameter at the rate of about 30 revolutions a minute. It had four electromagnets, two of which were on the wheel, and two were stationary and placed near the periphery of the revolving wheel. The north poles of the revolving magnets attracted the south poles of the stationary ones with sufficient force to move the wheel upon which the magnets revolved, until the poles of both the stationary and revolving magnets became parallel with each other. At this point, the conducting wires from the battery changed their position by the motion of the shaft; the polarity of the stationary magnets was reversed; and, being now north poles, repelled the poles of the revolving magnets that they had before attracted, thus producing a constant revolution of the wheel.

How Davenport actually reversed the flow of current through the electromagnets, his memoirs fail to state, but it probably consisted of some sort of a cam mechanism that did not operate very satisfactorily. But the satisfactory operation of his creation was of lesser importance than his successful attempts to convince others of the possibilities of this newly found aid to man. He had more followers who believed that he was developing a perpetual motion machine rather than a form of magnetic power. As the power developed by this early motor was only about 1/50th of a horsepower, those who viewed it, called it "mosquito power" and could see no practical value for such a device. His strong desire to establish his electric motor resulted in a neglect of his trade, a loss of customers, and near financial ruin. He sought encouragement from his village pastor who rebuked him with the statement, "If this wonderful power was good for anything, it would have been in use long ago." But undaunted by these setbacks, he took his motor to Middlebury College, there to seek the advice of the possessors of higher learning.

Professors Turner and Fowler of the Middlebury faculty watched a demonstration of the motor, recognized its potentialities, and advised Davenport to apply for a patent immediately. Elated, Davenport returned home and set about developing a new mechanism for reversing the flow of current through the electromagnets. In April 1835 he constructed a reversing mechanism that consisted of insulated segments rubbed by elastic flattened wires connected to the rotating armature. It was the inception of the modern commutator and it greatly improved the operation of Davenport's early motor. So enthusiastic was the press with this improvement that the August 13, 1835, issue of the Troy *Daily Budget* praised the accomplishments of Davenport and predicted that his name "would follow that of Henry's to the ends of the earth."

United States Patent Office.

THOS. DAVENPORT, OF BRANDON, VERMONT.

IMPROVEMENT IN PROPELLING MACHINERY BY MAGNETISM AND ELECTRO-MAGNETISM.

Specification forming part of Letters Patent No. 132, dated February 25, 1837

To all whom it may concern:

Be it known that I, THOMAS DAVENPORT, of the town of Brandon, in the county of Rutland, State of Vermont, have made a discovery, being an Application of Magnetism and Electro-Magnetism to Propelling Machinery, which is described as follows, reference being had to the annexed drawings of the same, making part of this specification.

The machine for applying the power of magnetism and electro-magnetism is described as follows:

The frame A may be made of a circular or any other figure, divided into two or more platforms, B and C, upon which the apparatus rests, of a size and strength adapted for the purpose intended.

The galvanic battery D is constructed by placing plates of copper and zinc E and F, alternately of any figure, in a vessel of diluted acid, G. From each vessel are two conductors, H and I, one from the copper and one from the zinc, leading to and in contact with copper plates K and L placed upon the lower platform. These plates or conductors are made in the form of a segment of a circle corresponding in number with the artificial magnets hereinafter described, placed around the shaft detached from one another and from the shaft, having a conductor leading from the copper plate of the battery to one of said plates on the lower platform, and another conductor leading from the zinc plate of the battery to the next plate on said lower platform, and so on alternately (if there be more than two plates on said lower platform) around the circle.

The galvanic magnets M N O P are constructed of arms or pieces of soft iron in the shape of a straight bar, horseshoe, or any other figure, wound with copper wire Q first insulated with silk between the coils. These arms project on lines from the center of a vertical shaft, R, turning on a pivot or point in the lower platform, said copper wires Q extending from the arms parallel, or nearly so, with the shaft, down to the copper plates K and L and in contact with them. The galvanic magnets are fixed on a horizontal wheel of wood, V, attached to the shaft.

The artificial magnets S T are made of steel and in the usual manner. They may be of any number and degree of strength and fixed on the upper platform, being segments of nearly the same circle as this platform; or, if galvanic magnets are used, (which may be done,) they may be made in the form of a crescent or horseshoe, with their poles pointing to the shaft. Having arranged these artificial magnets on the top of the upper circular platform, there will be a corresponding number of magnetic poles, the north marked 5 and the south pole 6. Now, we will suppose the machine to be in a quiescent state. The galvanic magnet No. 1 being opposite the north pole of the artificial magnets, the galvanic magnet No. 3 will, of course, be opposite the south pole No. 6, and the galvanic magnets Nos. 2 and 4 will be opposite each other, between the poles just mentioned. There being a corresponding number of copper plates or conductors placed below the artificial magnets around the shaft, but detached from it as well as from each other, with wires leading from the galvanic magnets to these plates and in contact with them, as before described, these wires will stand in the same position in relation to the copper plates that the galvanic magnets stand to the artificial magnets, but in contact with the plates.

Now, in order to put the machine in motion, the galvanic magnet No. 2, being changed by the galvanic current passing from the copper plate of the battery along the conductors and wires, becomes a north pole, while at the same time the magnet No. 4 is changed by the galvanic current passing from the zinc plate of the battery, and becomes a south pole. Of course the south pole of the artificial magnet No. 6 will attract the north pole of the galvanic magnet No. 2 and will move it a quarter of a circle. The south pole of the galvanic magnet No. 4, being at the same time attracted by the north pole No. 5, causes the said magnet No. 4 also to perform a quarter of a circle. The momentum of the galvanic arms will carry them past the centers of the poles Nos. 5 and 6, at which time the several wires from the galvanic magnets will have changed their positions in relation to the copper plates or conductors. For instance, the north pole No. 2 having now become a south pole by reason of its wire being brought in contact with the conductors of the zinc plate, and No. 4 having in like manner become a north pole, its wire having changed its position from the zinc plate to the copper plate, the poles of the galvanic magnets are, of course, now repelled by the poles

that before attracted them, and in this manner the operation is continued, producing a rotary motion in the shaft, which motion is conveyed to machinery for the purpose of propelling the same.

The discovery here claimed, and desired to be secured by Letters Patent, consists in—

Applying magnetic and electro-magnetic power as a moving principle for machinery in the manner above described, or in any other substantially the same in principle.

THOMAS DAVENPORT

Witnesses:
W. W. AYRES,
CHAS. A. COOK

FACSIMILE OF THE ORIGINAL PATENT

Figure 3. Facsimile of Davenport's patent on the electric motor

With continued encouragement from Professor Turner of Middlebury College, Professor Amos Eaton of Rensselaer Institute, Professor Joseph Henry of Princeton University, Professor Silliman of Yale University, and Professor Alexander Bache of Pennsylvania University, Davenport finally prepared a patent model and papers and presented them to the Patent Office. But misfortune followed him to Washington too, for the Patent Office burned and his model together with the papers was destroyed. However, with the aid of Ransom Cook, a prosperous manufacturer, another model was built and the papers rewritten. A photograph of this model, now on display at the Smithsonian Institution in Washington, D. C., is shown in Figure 2. He filed his claim again on January 24, 1837, and only 30 days later, on February 25, 1837, received United States Patent number 132, a reproduction of which is shown in Figure 3. Here, without question, is evidence that Thomas

Davenport is the inventor of the electric motor, about which the New York *Herald*, on April 27, 1837, so pompously stated:

A Revolution in Philosophy—Dawn of a New Civilization . . . most extraordinary discovery, probably the greatest of ancient and modern times—the greatest the world has ever seen, the greatest the world will ever see.

The electric motor was not the only "first" for Thomas Davenport, for he built a model of the first electric railway, and, on the first electrically-driven printing press, which he built in 1839, he printed his own publication, *The Electro-Magnet and Mechanics' Intelligencer*, the first American periodical on electricity. But, like the electric motor, they offered him no reward, and, in 1851, Thomas Davenport died penniless, with a broken heart, the patent on his electric motor having expired a few months prior to his death.

THE DE JACOBI MOTOR

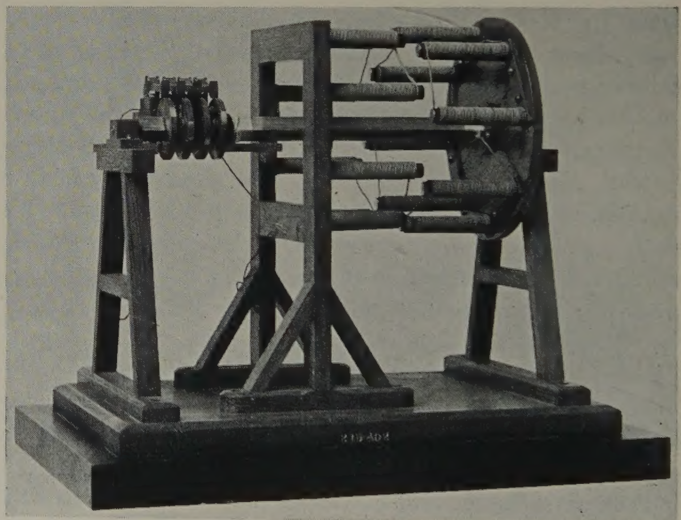
On December 1, 1834, a Russian scientist, Moritz-Hermann De Jacobi presented a paper before the Academy of Sciences in Paris in which he stated that he had obtained rotation by electromagnetic methods in May 1834. Since Davenport wrote in his memoirs that he first succeeded in producing motion electrically in July 1834, the question of actual priority in the point of time, is a close one. If the results obtained by De Jacobi in May 1834 were effected by the same apparatus that he described in his paper before the Academy in December 1834, then the priority must be conceded to him, but there is no proof available to show that such is the case. However, there is no doubt that the discoveries made by the two men were wholly independent.

In the year 1839, the Emperor Nicholas of Russia granted a sum of $12,000 to De Jacobi to enable him to prove that his electric motor had practical application. De Jacobi had a boat constructed, 28 feet long and 7 feet wide, which was propelled by means of paddles connected to an electric motor of his design. Figure 4 shows a model of the motor used on this craft. It consisted of two sets of electromagnets, eight in each set, one set being stationary and the other fastened to a rotatable wheel. Current from a bank of batteries was delivered to the rotating "star" through a commutator which reversed the polarity of the magnets eight times each revolution. The commutator used by De Jacobi appeared to be of better design than that used by Davenport and is very similar to the ones used today.

The De Jacobi boat, the first practical application of an electric motor, carried about 14 passengers and was powered by 320 Daniell cells, which is equivalent to about 100 of our present-day 6-volt storage batteries. In its trip up the Neva River it never achieved a speed greater than three miles an hour and consequently offered very little competition to man-propelled craft. The weight of the many batteries made the accomplishment impractical and it shortly was declared a failure. The cause of the failure was obvious, but the value of the electric motor as a new form of marine power was not forgotten.

THE PAGE MOTOR

Charles Grafton Page, a physician from Salem, Mass., performed many electromagnetic experiments during the middle of the 19th century, the accounts of which may be found in Silliman's *American Journal of Science and Art*, the outstanding science publication of that time. In 1841 he became one of the two principle examiners in the United States Patent Office, and from 1844 to 1849 held the chair of chemistry at Columbian College, now George Washington University. In 1846 he built a small reciprocating electromagnetic engine which operated in an entirely different manner from that of Davenport's and De Jacobi's machines and, though the principle was sound, it never gained much popularity. Its motion resembled very much that of a steam engine's piston and in appearance was quite similar. It consisted of a hollow electromagnetic coil and an iron bar which was free to move within the coil. Both the coil and the bar were held vertically so that the bar was in a position of rest outside the coil when the coil was de-energized. Once current was allowed to flow through the coil, the bar would be attracted upward. Then when the current in the coil was interrupted, the bar would fall downward. This vertical motion was transferred to a flywheel by means of a crankshaft. A commutating device, fastened to the crankshaft, automatically interrupted the flow of current to the coil at the proper time. In 1850, Page improved upon this single-acting motor by adding another solenoid which would pull the rod in the



Courtesy Smithsonian Institution

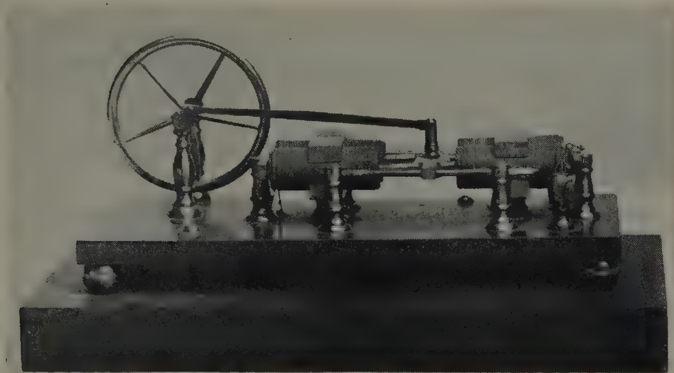
Figure 4. The De Jacobi electric motor

other direction and thus not depend upon the force of gravity for assistance. This improved model, for which Page was issued United States Patent number 10,480 dated January 31, 1854, is shown in Figure 5.

Although Page's motor did not receive public acclamation, it is worthy to note, as in the case of De Jacobi, that he made an outstanding contribution in publicizing the feasibility of such a device. In 1851, the Congress voted $50,000 to allow Page to construct an electric locomotive. A very interesting account of this early experiment may be found in

the first American textbook on electric motors entitled "The Electric Motor and Its Applications," by Thomas C. Martin and Joseph Wetzler. Portions of this account as found on page 20 of this book are given here.

Professor Page made a trial trip with his electromagnetic locomotive on Tuesday April 20, 1851, starting from Washington, along the tracks of the Washington and Baltimore Railroad. His locomotive was of 16 horsepower, employing 100 cells of Grove nitric acid battery, each having platinum plates 11 inches square. The progress of the locomotive was at first so slow that a boy was enabled to keep pace with it for several hundred feet. But the pace soon increased, and Bladensburg, a distance of about five miles and a quarter, was reached, it is said, in 39 minutes. When within two miles of that place, the locomotive began to run at a rate of 19 miles an hour, or seven miles faster than the greatest speed theretofore attained. This velocity was continued for a mile, when one of the cells cracked entirely open, and, as a consequence, the propelling power was partially weakened. Two of the other cells subsequently met with a similar disaster. It was found that the least jolt, such as caused by the end of a rail a little above the level, threw the batteries out of working order, and the result was a halt. This defect could not be overcome and Professor Page reluctantly abandoned his experiments in this special direction.



Courtesy Smithsonian Institution

Figure 5. The Page electric motor

Page knew of Davenport's accomplishments in the field of electromagnetism and much correspondence passed between the two in which the merits of their individual devices were discussed. There were two major points of disagreement between them which time has shown that Davenport held the sounder theory. Page consistently adhered to the theory that the best results would be attained by simply discontinuing the flow of current to the electromagnets, without reversing the polarity. Davenport strongly persisted that the reversal should be performed. On the other point of argument, Page claimed that the size of the electric motor was definitely limited, since his experiments showed that the smaller machines were more efficient. Davenport could not see any sound foundation for such a claim and stated that such an idea affected him with "peculiar disagreeableness."

CONCLUSIONS

The efforts of these early pioneers, although seemingly failures, laid the necessary foundation for the development of the modern electric motor. Their accomplishments proved disappointing not because the soundness of the electric motor as a means of converting energy was in doubt, but rather because the device was born too soon. Since most crafts and skills were performed satisfactorily by hand at that time, the need of such labor-saving devices for mass production was not in demand. Also, the expense of the batteries to drive these primitive motors made its use prohibitive. Around the year 1850, Robert Hunt, an English natural philosopher, analyzed the relative cost of power obtained from a steam engine and from an electric motor using a battery and found that the electric power was 25 times more expensive than steam power. It did not occur to these early experimenters that the reverse process of electromagnetism was possible—that of the d-c generator. It was not until 1860 that Antonio Pacinotti, an Italian scientist, showed conclusively that by reversing the operation of the electric motor, "motion would produce electricity." Even after that discovery, industry was slow to make use of this knowledge. It was not until 1886 that the electric motor found its place in the American home when the Curtis, Crocker, Wheeler Company began manufacturing battery-operated motors for sewing machines. It was not until 1887 that the City of New York decided to lay the first tracks for its famous "elevated." It was not until 1897 that the first electric automobile made its appearance. It was not until 1910 that the first electrically-driven washing machine was introduced to the American housewife. And it was not until 1915 that the *U.S.S. Mexico* the first electrically-propelled battleship, was launched.

Nevertheless, much credit should be given to those men who had the vision to foresee the marvels of their bundles of copper and steel. First to Thomas Davenport, the inventor of the electric motor; second, to Moritz-Hermann De Jacobi, who was the first to apply the electric motor practically to marine propulsion; and finally, to Charles Grafton Page, who was probably the first to apply the electric motor successfully to rail locomotion. Without a doubt, the most outstanding of these men is the Brandon blacksmith. In spite of the paucity of both his educational and financial advantages, he achieved a goal which others, far more fortunate than he, never had gained. His education could not have exceeded any more than three years of study based on today's standards and he was not gifted by any grant of money for the continuation of his experimental studies. Both De Jacobi and Page were learned men, fully equipped to battle the problems of their newly found science—electromotion. Moreover, their struggles were cushioned heavily by large governmental grants. It required supreme effort for a man, completely lacking such aids, to follow through to the time of his death an ambition that sprang from mere curiosity and resulted in one of man's most useful devices. It is hardly necessary to point out what fortunes would have been his had he renewed his patent rights and had he lived a few decades longer. The claims of his patent were extremely broad:

Applying magnetic and electromagnetic power as a moving principle for machinery in the manner above described, or in any other substantially the same in principle.

What with an estimated 50 million motors manufactured in the United States during the year 1947, a possessor of such a

claim easily could mass a fortune far exceeding that of Rockefeller and Carnegie combined. But neither fame nor fortune was the lot of Thomas Davenport, a man who rightly deserved both.

In 1891 Franklin Leonard Pope, a charter member of the AIEE who became its president in 1884, wrote a series of five articles for *The Electrical Engineer* entitled: "Inventors of the Electric Motor." Although the title carried the word "inventor" in the plural, he proved conclusively that Thomas Davenport alone was the inventor of the electric motor. His evidence can be considered to be most trustworthy since he had opportunity to converse with living witnesses and examine original documents. On February 24, 1891, exactly 54 years, less a day, after Davenport had received his patent on the electric motor, Pope read a paper before a meeting of the AIEE in which he sought "to rescue from impending oblivion the true story of the invention of the electric motor." But now, more than 110 years since United States Patent number 132 was issued, the darkness of that oblivion seems to have engulfed the accomplishments of this early American inventor. It would seem fitting that, at this time, some lasting tribute be made to perpetuate the memory of Thomas Davenport. Throughout the history of our electrical science fitting honor has been bestowed upon such men as Alessandro Volta, Andre-Marie Ampere, Georg Simon Ohm, James Watt, Joseph Henry, Michael Faraday—such that their names are of common usage in the classroom and in industry. Would it not seem appropriate that Thomas Davenport be honored in a similar manner? Could not the unit of performance of rotating engines, the horsepower, which is used so much in connection with electric motors, be changed to "davens," in honor of the inventor? What procedure must be followed to effect such a change, I do not know, but an expression of our tribute to this almost forgotten American seems to be wanting, and the opportunity to change this archaic term may present the occasion to bestow this belated honor.

REFERENCES

1. The Electric Motor and Its Applications, **T. C. Martin, Joseph Wetzler.** W. J. Johnston Co., Ltd.

2. Biography of Thomas Davenport, **Walter Rice Davenport.** The Vermont Historical Society, Montpelier, Vt.

3. Chronological History of Electrical Development. National Electrical Manufacturers Association, New York 17, N. Y.

4. Inventors of the Electric Motor, **Franklin Leonard Pope.** *Electrical Engineer*, series of five articles in the following issues: January 7, January 14, January 21, January 28, and February 4, 1891.

New Shunt and Inductor Designs

The satisfactory measurement of surge currents presents peculiar difficulties because of the high values of impulse current obtained in millionths of a second, and because of the high-frequency components of the surge current. Important advances are being made in the design of shunts and mutual inductors for measuring magnitude and rate of change of surge currents by the National Bureau of Standards.

After a rather complete theoretical comparison of the various types of shunts which might fulfill necessary predetermined requirements, it was concluded that a shunt consisting of two coaxial tubes, with the potential-measuring circuit brought out as a coaxial cable from the smaller tube, would be most satisfactory. Advantages of the coaxial-tubular design include a more nearly constant impedance over a wide frequency range, minimum inductive pick-up for current carrying parts of the surge generator, and freedom in location of ground connections at the surge generator. Two workable models already have been designed at the bureau.

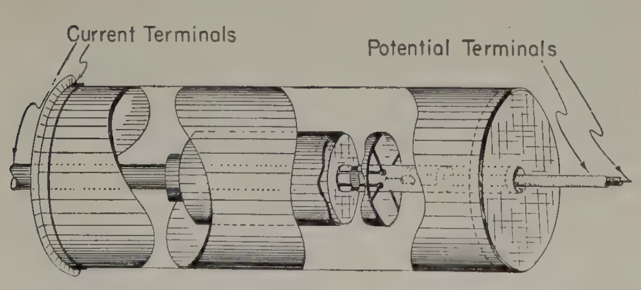


Figure 1. Cut-away drawing of the mutual inductor used in determining the rate of change of current with time during a high-current surge discharge. The innermost tube is the primary of the inductor, while the secondary consists of the shorter middle tube, the portion of the inner tube within the middle tube, and a ring connecting the two tubes. The large outermost tube provides a return lead for the primary current. Thus, the least possible inductance is added to the discharge circuit. The outer current return tube also serves as an electrostatic shield for the secondary circuit. The voltage induced in the secondary —a measure of the rate of change of current in the primary—is determined from the record of a cathode-ray oscillograph connected across the secondary by potential leads which form a coaxial cable at right

For other experiments involving high-current surges, the rate of change of current with time was obtained by use of a mutual inductor. The primary of the mutual inductor is connected in the heavy-current discharge circuit, and its secondary is connected to the oscilloscope. The voltage record obtained on the oscilloscope is then a function of the rate at which the current is changing and of the known mutual inductance of the inductor. To be suitable for this purpose a mutual inductor must have a low mutual inductance (about 0.05 microhenry) computable from its dimensions, and its effective inductance should be constant for frequencies up to 50 megacycles per second or higher.

As no previously known design of mutual inductor would fulfill these requirements, a coaxial-tubular mutual inductor was designed and a 0.05-microhenry inductor was constructed (see Figure 1). As in the case of the shunt, the coaxial-tubular construction tends to minimize inductive pick-up from any magnetic fields that may be present. It is expected that this type of inductor may prove useful in other applications requiring measurements at high frequency.

Steady-State Analysis of Aircraft D-C Generators

ERNEST VAN VALKENBURG   WHITNEY MATTHEWS
MEMBER AIEE

THE SOLUTIONS to many steady-state d-c generator problems would be less complex if there were a simple yet accurate means for expressing analytically the machine's electromagnetic characteristics. Particularly, problems of voltage and load control and certain aspects of dynamo design might be approached with greater certainty if trial and error processes could be abandoned for a direct mathematical investigation. The purpose of this article is to present the development of such an analysis. This mathematical tool has been applied successfully to several aircraft generators.

Most electrical characteristics of d-c generators are nonlinear because of the saturation property of ferromagnetic materials. This property can be represented adequately by an empirical hyperbolic tangent function. That is, let the magnetization characteristic of a shunt field generator be represented by

$$\phi = A\tanh(BN_fI_f + C) + D \tag{1}$$

where ϕ is the no-load flux, N_fI_f is the field ampere-turns per pair of poles or excitation, and A, B, C, and D are empirical constants. Then the steady-state no-load terminal voltage E_t is

$$E_t = Kn[A\tanh(BN_fI_f + C) + D] \tag{2}$$

where n is the speed and K is a design constant.

Figure 1 indicates how accurately equation 2 can be applied. The maximum error for the three generators is from one to two per cent, which is less than deviations of the measurements due to hysteresis effects.

The steady-state load characteristics are obtained by incorporating the three effects due to armature current with equation 2. These effects are armature IR drop, direct axis armature reaction, and cross magnetization. The first two effects are treated in the conventional manner, and the latter effect is derived by a definite integration of equation 2. Combining these effects yields

$$E_t = Kn\left[\frac{A}{2BN_cI_a}\log_e\left[\frac{\cosh[B(N_fI_f - N_dI_a + N_cI_a) + C]}{\cosh[B(N_fI_f - N_dI_a - N_cI_a) + C]}\right] + D\right] - E_a \tag{3}$$

Here I_a is the total armature current; N_c and N_d are the effective cross magnetization turns and direct axis reaction turns, respectively; and E_a represents the IR drop and contact potentials resulting from armature current.

Application of this equation to a 2-kw 22-pound 6,000-rpm aircraft generator showed a maximum error within the rated operating range (20 to 40 volts) of less than one volt.

In order to adapt this analysis to a self-excited system, the inverse function of equation 1 is used, since it is convenient to treat excitation as the dependent variable. A typical characteristic of self-excitation is expressed by

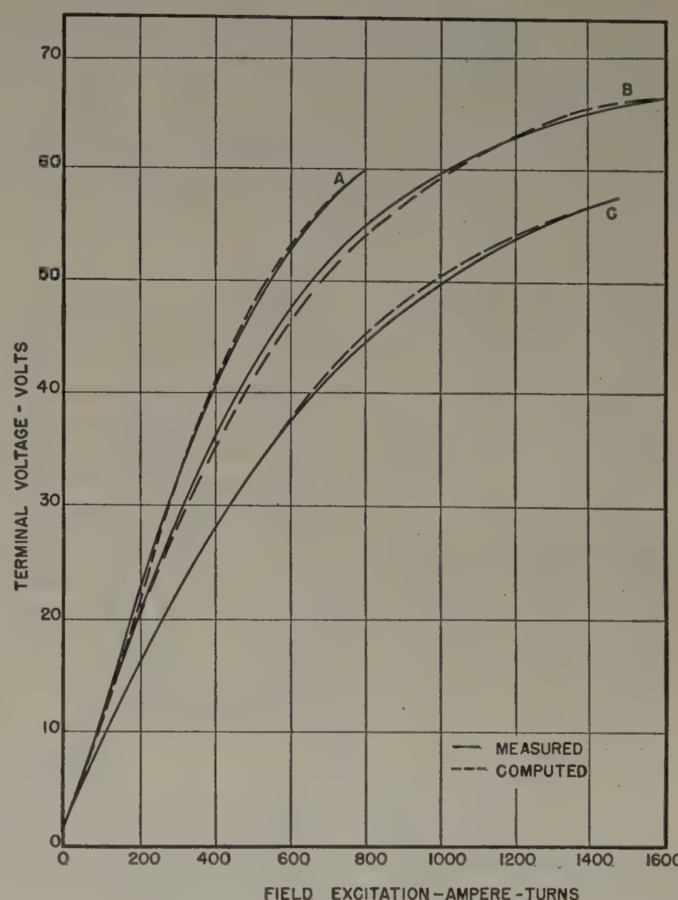


Figure 1. No-load saturation characteristics

$$R_f = \frac{2BN_fE_t}{\log_e\left[\dfrac{\exp[2BN_cI_a(E_t - DKn + AKn + E_a)/(AKn)] - 1}{\exp[2BN_cI_a] - \exp[2BN_cI_a(E_t - DKn + E_a)/(AKn)]}\right] - 2C + 2BN_dI_a} \tag{4}$$

where R_f is the total resistance in the shunt field circuit required for any steady-state condition of voltage, load, and speed.

Thus, it is demonstrated that the steady-state characteristics of a d-c generator can be analyzed mathematically to a practical degree of accuracy by employing hyperbolic functions. This analysis has been applied with equal success to compound and compensated machines.

Digest of paper **48-250**, "Steady-State Analysis of Aircraft D-C Generators," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Ernest Van Valkenburg is a physicist, and **Whitney Matthews** is head of the control systems subsection of the electricity division; both with the Naval Research Laboratory, Washington, D. C.

Inductive Co-ordination in Rural Areas

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THE SOLUTION of numerous inductive co-ordination problems involving rural power and communication circuits has indicated that generators, transformers, and other equipment used on rural power lines should be designed to generate as little harmonic current as practicable. Noisy circuits caused by induction from power lines cannot, by any means, be cleared up by the telephone people without the co-operation of the power suppliers. In general, power equipment containing iron in its magnetic circuit generates voltages whose frequencies are multiples or harmonics of the fundamental frequency. The magnitude and frequency of these harmonic voltages depend on the type of magnetic material and the portion of the magnetization curve on which the equipment is operating.

Although it cannot be stated that any particular value of harmonic current or voltage will cause a noise problem, experience has indicated that noise problems attributable to harmonics arising in generators probably would be avoided if the generators were designed with an open circuit TIF (telephone influence factor) value no higher than 15. In many instances manufacturers have found it necessary to change designs considerably to meet this TIF limit. These changes usually consisted of skewing the stator slots, changing the rotor pole face contour, and partially closing the slots. One manufacturer has reported the results of experimental changes made on one of his machines as shown in Table I.

Table I. Results of Experimental Changes

	Test Condition	Voltage TIF No Load
1	Original design—open slots	354
2	Stator slots skewed 1 slot-pitch, open slots	17.4
3	Stator slots skewed 1 slot-pitch, open slots, rotor pole face contour changed to have gap at tip double gap at center but same average air gap as original machine	30.2
4	Same pole face contour as in 3 above, stator slots skewed 1.04 slot-pitch and slots partially closed	10.4
5	Stator slots skewed 1.04 slot-pitch, slots partially closed, poles of regular contour and uniform air gap	12.1

Name plate data—62.5 kva, 0.8 power factor, 60 cycle, 1,200 rpm, 480 volts, Y-connected.

In some instances distribution transformers have been found to be the source of sufficient harmonic current in the range of 180 to 900 cycles to render comparatively well balanced telephone circuits inoperable. These large harmonic currents generally resulted when transformers, designed to operate at flux densities near the saturation point, were operated at a voltage somewhat in excess of their ratings. However, it was found that with transformers designed to have an exciting current $I \cdot T$ product of about 15 or less per kilovolt-ampere on the 120-volt base, problems of this sort practically could be eliminated. The voltage applied to the transformer, of course, must not appreciably exceed the rated voltage. Table II presents a comparison of the harmonic analysis of two 3-kva 7,200/120-volt transformers, one with an acceptable $I \cdot T$ product and the other not acceptable.

Table II. Harmonic Analysis of Two Transformers

Frequency	Transformer 1 (Acceptable)	Transformer 2 (Not Acceptable)
Over-all I·T product	36	380
180-cycle contribution	6	18
300-cycle contribution	21	109
420-cycle contribution	8.3	155
540-cycle contribution	3.6	125
660-cycle contribution	12	79
780-cycle contribution	11	94

Long rural power lines sometimes give rise to another type of inductive co-ordination problem. If the power lines approach one-quarter wave length at frequencies in the audible range a resonant condition may exist. Thus even with a power source of reasonably good wave shape, harmonic-voltage rise along the lines may result. Results of actual measurements of harmonic voltages along a 7.2/12.5-kv power line are shown by Table III.

By terminating each phase of the power line with a device having an impedance approximately equal to the characteristic impedance of the line, noise in parallel telephone circuits has been reduced by 6 decibels or about 50 per cent.

Problems involving 60-cycle induction often prove more difficult to solve. Isolating transformers and the so called "sucker transformer" have been used to reduce interference in some instances. The isolating transformer, in effect, provides a transposition in a single-phase multigrounded-neutral power line so that the induction in one part of the exposure opposes that in the other part of the exposure. The "sucker transformer" causes equal currents to flow in the phase and neutral conductors of single-phase multigrounded-neutral lines, thereby greatly reducing the inductive influence of the power line.

Table III

Frequency	Distance From Source		
	24 Miles	34 Miles	38 Miles
Over-all voltage TIF	12.1	18.0	21.1
180-cycle component	0.3	0.3	0.3
300-cycle component	6.3	7.1	6 3
420-cycle component	2.9	3.9	3.9
540-cycle component		1.4	1.0
660-cycle component	2.8	3.6	3.2
780-cycle component	7.6	10.8	17.4
900-cycle component	0.9	1.6	2.6
1,020-cycle component	3.8	6.1	6.5

Digest of paper **48-244**, "A Survey of Inductive Co-ordination in Rural Areas," recommended by the AIEE communications and transmission and distribution committees and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

M. W. Rothpletz and **H. S. Williams** are electrical engineers in the technical standards division, Rural Electrification Administration, Washington, D. C.

Diode Circuit Analysis

R. H. DISHINGTON
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Diode circuits may be analyzed by a basic method less complex than methods now in use. The nonlinear tube characteristic is analyzed and an equivalent circuit is suggested to which most ordinary applications can be reduced. The method may be applied to various diode and multielement tube circuits, such as a diode modulator.

IN designing or teaching the operation of circuits involving diodes, as many diversified methods of analysis are applied as there are types of application. Each of these different methods of analysis has become highly specialized to give accuracy, but this specialization results in a departure from the more basic principles which must be common to all diodes and diode circuits. Consequently there is a need for a simple, basic method, which will apply to all commonly used diode circuits, by which they can be analyzed and also compared physically. Because the diode is a nonlinear circuit element, the whole problem becomes that of finding a system for analyzing the nonlinear current pulse resulting. Once found, this method applies not only to diodes, but to any other similarly nonlinear device utilized in the same fashion.

THE DIODE CHARACTERISTIC

Generally, diodes are either gas-filled or high-vacuum tubes. Inasmuch as the gas tube characteristic is simpler to work with, and can be considered to be an end condition of the high-vacuum diode characteristic, the latter will be used, and modifications for using gas tubes introduced later. The nonlinearity of the static-plate characteristic is illustrated in Figure 1. It is well known that a curve of this type can be expressed as follows:

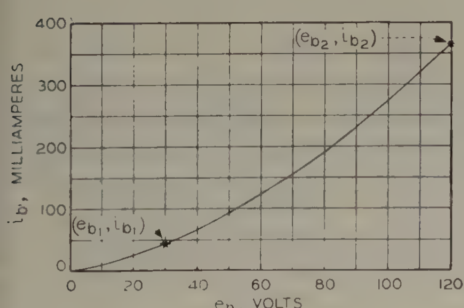

Figure 1. Static plate characteristic of a diode

$$i_b = Ke_b^{\alpha s} \tag{1}$$

where i_b is the total instantaneous plate current, e_b is the total instantaneous plate voltage, and K and α_s are constants over most of the curve. The relationship in equation 1 is assumed to be correct for both static and slowly varying voltage and current.

The constant K is not directly used in the methods to follow, making its determination unnecessary. Usually, the exponent α_s is about 3/2, a value theoretically verified by a form of equation 1 called Child's law, although it can have a value anywhere from 1.5 to 1.2. An accurate calculation of α_s can be made in several ways. If the values on the curve in Figure 1 are plotted on log-log paper, the slope of the straight line resulting gives α_s. A value almost as accurate can be obtained by the 2-point method. Thus

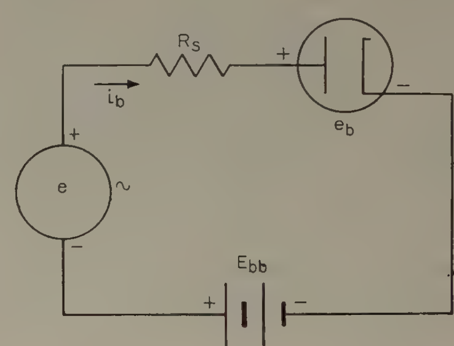

Figure 2. Unsimplified equivalent circuit

$$\frac{i_{b2}}{i_{b1}} = \left(\frac{e_{b2}}{e_{b1}}\right)^{\alpha_s} \tag{2}$$

where e_{b2} is taken at the highest point on the static characteristic, and e_{b1} is approximately one fourth of e_{b2}, as in Figure 1. Values of α_s for several commonly used diodes are listed in Table I.

THE EQUIVALENT CIRCUIT

Fortunately, upon making a few simplifying assumptions, almost any diode circuit, such as a power rectifier or modulator or detector, can be reduced to what is known as the *equivalent circuit*. It is this basic circuit which relates all of the various applications. Figure 2 shows that it contains two voltages and two resistors, one linear and one nonlinear. The voltage source e is sinusoidal and is assumed to have no internal impedance. E_{bb} is a constant-voltage source, also assumed to have no internal impedance. Both e and E_{bb} are considered as algebraic quantities which are positive if they tend to make the diode plate positive, and negative in the reverse polarity. Except for the tube, all series resistance in the circuit is lumped to form R_s. Because of the nonlinear tube characteristic, the current pulse through the circuit will not be sinusoidal, even though the impressed voltage e is sinusoidal. A nonsinusoidal current produces a propor-

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R. H. Dishington is research engineer, Douglas Aircraft Company, Santa Monica, Calif. However, work for this article was done while the author was a member of the faculty at University of Southern California, Los Angeles, Calif.

The author wishes to acknowledge the aid of H. L. Schauer in providing many laborious checks of the system given herein.

tionally nonsinusoidal voltage drop in R_s. This is the source of most of the difficulty in the analysis. A simplification results if R_s is added to the tube resistance to form what is called the combination unit (Figure 3). The voltage e_d across this combination is

$$e_d = e_b + i_b R_s \tag{3}$$

It can be shown graphically (Figure 4) that

$$i_b = K_1 e_d^{\alpha c} \tag{4}$$

where e_d is the combination voltage, K_1 is a new constant, and α_c is the new combination exponent which is constant

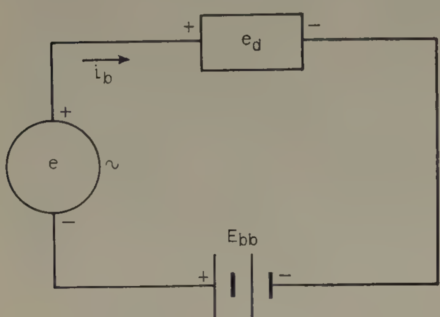

Figure 3. Simplified equivalent circuit including the combination unit

over most of the curve. To determine α_c, a method is employed similar to that used in finding α_s. Three things determine α_c: the original α_s, the series resistance R_s, and the ratio of e_b to i_b for at least one point of the static curve. Their relationship is derived in Appendix I, and the results are plotted in Figure 5. The highest point on the static characteristic is taken to find R_{T_2}. Table I includes a list of values of R_{T_2} for various tubes. It can be seen from the

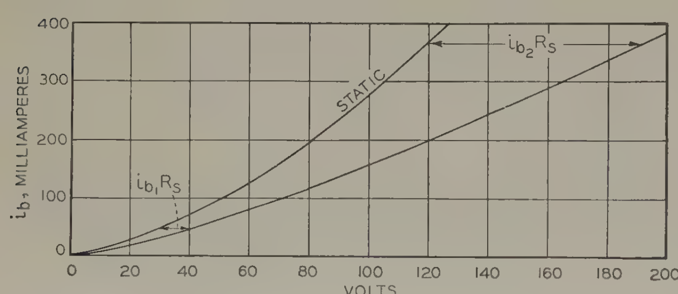

Figure 4. Combination characteristic of a diode in series with R_s

curves in Figure 5 that α_c can have any value between α_s, where R_s is zero, and 1.0, where R_s is infinite.

CLASS OF OPERATION

The type of current pulse that flows upon the application of a sinusoidal input voltage e depends upon the polarity and magnitude of E_{bb}. For example, if E_{bb} is negative and equal to e_{max}, no current will flow; whereas, if the voltage E_{bb} is positive and greater than e_{max}, current will flow for a full cycle. Other values of E_{bb} determine what part of a cycle current flows, and classes of operation are defined on the basis of this flow angle. The standard definitions of class *A*, *AB*, *B*, and *C* operation are used, minus any references to grid voltages or currents. Pulses of current for various classes of operation are pictured in Figure 6.

Table I. Values for Tube Characteristics

Tube	α_s	R_{T_2}	Tube	α_s	R_{T_2}
1A3	1.24	4,000	*6H6*	1.30	500
1B3GT	1.40	11,650	*12Z3*	1.42	107
1V	1.45	154	*25Z5*	1.45	100
5T4	1.46	139	*35Z3*	1.45	71
5U4G	1.48	183	*35Z4*	1.44	62
5W4	1.26	426	*45Z3*	1.48	127
5Y3	1.49	333	*45Z5GT*	1.46	55
5Z4	1.40	112	*81*	1.48	483
6AL5	1.36	171	*117P7GT*	1.44	76
6X5	1.46	224	*117Z3*	1.45	89
6ZY5G	1.45	308	*117Z6*	1.45	118

THE PLATE CURRENT PULSE

A current pulse of the type shown in Figure 6 can be considered as a d-c or average value plus a number of a-c components. By expanding equation 4 into a binomial series and simplifying,

$$i_b = I_b + I_{p1m}\cos\omega t + I_{p2m}\cos 2\omega t + \ldots + I_{pnm}\cos n\omega t \tag{5}$$

Each of the components is determined by the angle of flow, the exponent α_c, and the peak current i_{bmax}. An analysis of

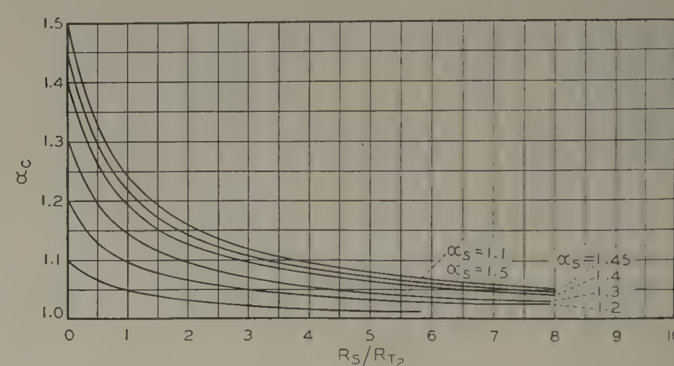

Figure 5. Variation of combination α_c with R_s, R_{T_2}, and α_s

these components was made by Terman and Roake,[1] in which the ratio of each component to i_{bmax} was plotted as a function of the angle of flow and α_c. Examination of Figure 6 reveals a relationship between the voltages and the angle of flow

$$\cos\theta_p = -\frac{E_{bb}}{e_{max}} \tag{6}$$

where θ_p is one half of the total angle of flow. Thus, the ratios, I_b/i_{bmax}, I_{p1m}/i_{bmax}, and so forth, also can be found as functions of E_{bb}/e_{max} and α_c, without actually finding the angle θ_p (Figure 7).

SOLUTIONS OF THE EQUIVALENT CIRCUIT

Several types of solutions to the equivalent circuit exist, depending upon which quantities are known and unknown. The first type is known as the *backward* solution, because E_{bb} and I_b are given, and the input voltage e_{max} necessary to produce I_b is to be found. The solution is given in graphical form (Figure 8), because the final form of the equation relating the variables cannot be solved reasonably by any other method. Appendix II contains the derivation. The curves show the ratio E_{bb}/e_{max} as a function of E_{db}/E_{bb} and α_c. In any practical problem, the series resistance R_s and

the static tube characteristic are available. Consequently, by knowing α_c and E_{bb}, e_{max} can be found if E_{db} is obtained as follows. On the static curve, find $e_b]_{I_b}$ that corresponds to the given I_b. Then

$$E_{db}=e_b]_{I_b}+I_bR_s \tag{7}$$

Now compute E_{db}/E_{bb}. On the curves (Figure 8), find E_{bb}/e_{max}. Calculate e_{max}.

A second type of problem is solved by what is called the *foreward* solution. Given e_{max} and R_{bb}, where

$$R_{bb}=-\frac{E_{bb}}{I_b} \tag{8}$$

the solution consists of finding the actual values of E_{bb} and I_b. Again, as derived in Appendix III, the final solution is given in graphical form (Figure 9). In a practical problem, having the tube characteristic and α_c, i_2 is found as the ratio of the known e_{max} to the known R_{bb}. The voltage E_{bb} can be found as follows. On the static tube curve, find $e_b]_{i_2}$ that corresponds to the calculated i_2. Then

$$E_2=e_b]_{i_2}+i_2R_s \tag{9}$$

From equation 9, find the ratio E_2/e_{max}. On the curves (Figure 9), find E_{bb}/e_{max}. Calculate E_{bb}.

There are certain other special solutions of the equivalent circuit, which will be mentioned later.

POWER RECTIFIERS

Direct application of the two solutions just discussed can be made to power rectifiers. Two basic types of power rectifiers are commonly used, one with a choke input filter and the other with a capacitor input filter. Those with choke input filters require a special solution and will be discussed later. Those with any type of filter which has capacitor input, such as the simple capacitor filter, the pi filter, or the multiple pi filter, can be analyzed by the methods outlined. It is only necessary to convert to the equivalent circuit.

In the case of a full-wave rectifier (Figure 10), the analysis is carried out for only half of the circuit, each half being assumed identical. The voltage e of the equivalent circuit corresponds to the open-circuit voltage across the full transformer secondary winding for a half wave circuit, and across half of the secondary for the full-wave. The series resistance normally includes only the transformer resistance, which is usually 200 ohms in the equivalent circuit for either half or full wave. This includes both the secondary winding resistance (all or half) and the reflected primary winding resistance (all or one-fourth), a large effect being produced by the primary winding. Values other than 200 ohms should be used if the actual resistance is known. Except for unfiltered power supplies, neither the load resistance nor any choke resistance is included in R_s, because all of these resistors are assumed to be within the two points

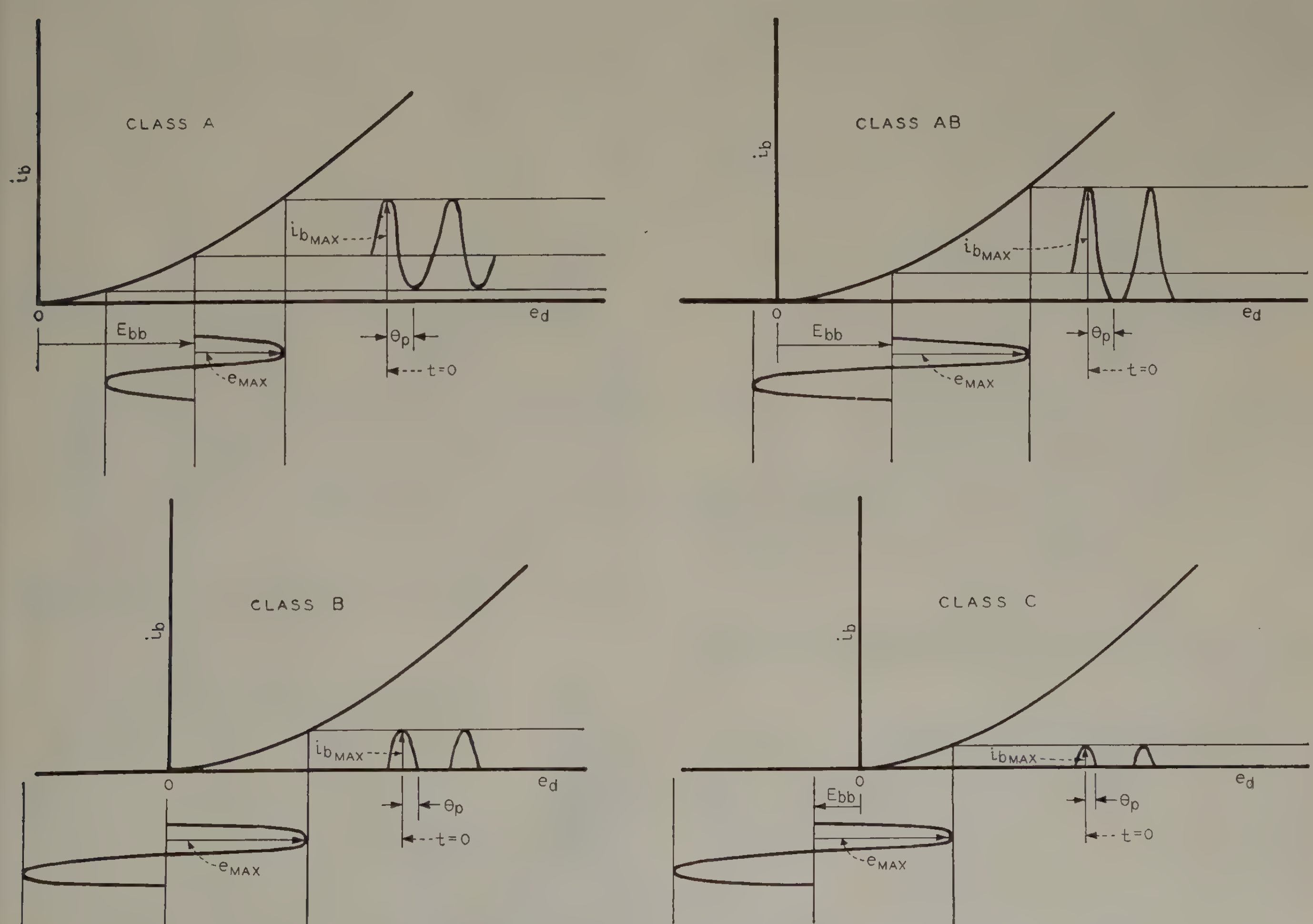

Figure 6. Typical classes of operation

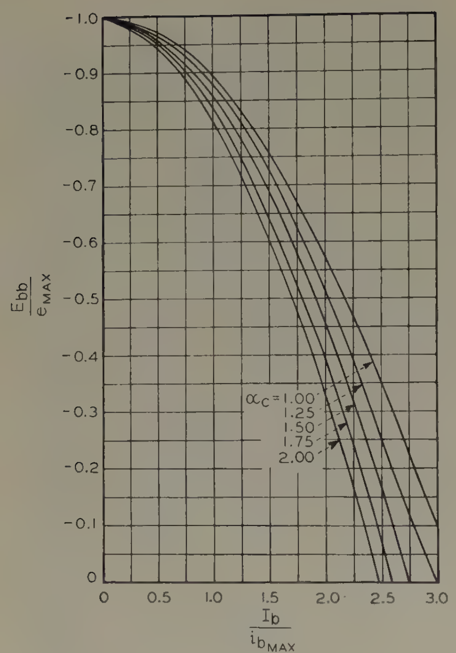

Figure 7. Ratios of average current to peak current for various angles of flow

across which E_{bb} appears. For example, consider Figure 10. If the filter is of the type generally used, the voltage between A and B, across the input capacitor is almost constant except for a ripple which can be neglected in the solution with little error. Thus

$$E_{bb} = -[E_{DC} + I_{DC} \text{ (all choke resistances)}] \tag{10}$$

In the half-wave rectifier, I_b equals I_{DC}; but in the full-wave rectifier, I_b equals $I_{DC}/2$.

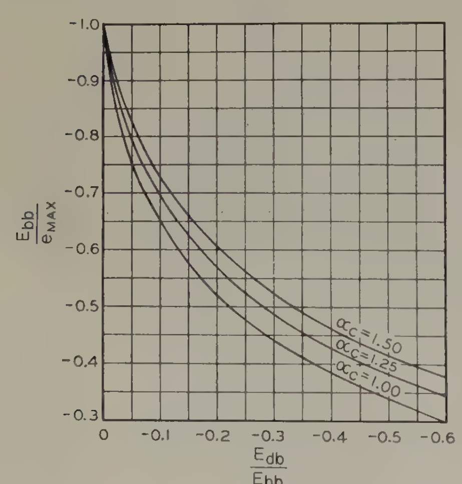

Figure 8. Solution of the backward problem

Example. Calculate the input voltage necessary to produce 300 volts at 100 milliamperes in the output of the rectifier of Figure 10.

1. Assume each choke resistance is 120 ohms.
$E_{bb} = -[300 + 100 \times 10^{-3}(2 \times 120)] = -324$ volts

2. Assume $R_s = 200$ ohms. From Figure 5, $R_{T_2} = 333$.

$$\frac{R_s}{R_{T_2}} = \frac{200}{333} = 0.667$$

From Figure 5, $\alpha_s = 1.49$, so $\alpha_c = 1.28$.

3. $I_b = \dfrac{I_{DC}}{2} = 50$ milliamperes

From the static tube characteristic, Figure 1,

$e_b]_{50ma} = 32$ volts
$E_{db} = 32 + 50 \times 10^{-3} \times 200 = 42$ volts

4. $\dfrac{E_{db}}{E_{bb}} = \dfrac{42}{-324} = -0.13$

From the curves, Figure 8, for $\alpha_c = 1.28$,

$$\frac{E_{bb}}{e_{max}} = -0.66$$

and

$$e_{max} = -\frac{324}{-0.66} = 490 \text{ volts peak}$$

Thus, the transformer secondary winding must produce about 490 volts on either side of the center tap.

5. To find i_{bmax}, the curves in Figure 7 are consulted.

$$\frac{I_b}{i_{bmax}} = 0.16$$

$$i_{bmax} = \frac{50}{0.16} = 312 \text{ milliamperes}$$

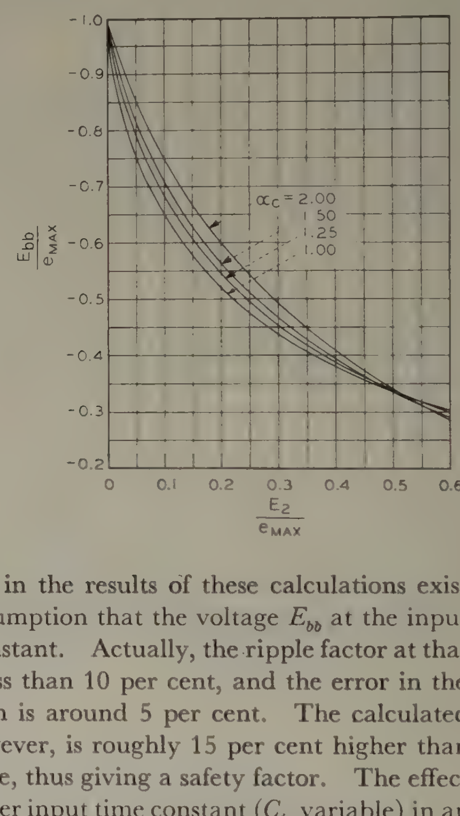

Figure 9. Solution of the forward problem

Inherent errors in the results of these calculations exist because of the assumption that the voltage E_{bb} at the input to the filter is a constant. Actually, the ripple factor at that point is usually less than 10 per cent, and the error in the voltage calculation is around 5 per cent. The calculated peak current, however, is roughly 15 per cent higher than the measured value, thus giving a safety factor. The effect of changing the filter input time constant (C_{in} variable) in an actual case is shown in Figure 11.

After the rectifier has been designed to produce the desired full-load output, a knowledge of the load characteris-

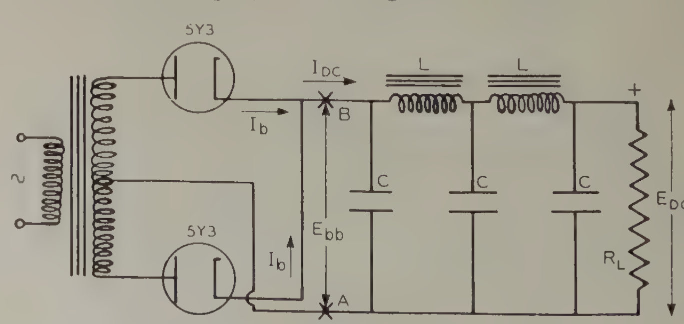

Figure 10. Full-wave power rectifier, capacitor input

tic is of value in showing the regulation. This can be obtained by using the *forward* method. The e_{max} determined in the last example is considered to be constant, whereas the load resistance is varied. Points for about four values of R_L will be adequate. Special care must be given to the determination of the proper R_{bb} as in equation 8. R_{bb} is defined as the ratio of the voltage across the filter input E_{bb} and the average current in one tube. Consequently, for a half-wave circuit, R_{bb} is all of the choke resistances plus the load resistance; but for a full-wave circuit, R_{bb} is twice the sum of all the choke resistances and the load resistance.

Example. Plot the load characteristic of the rectifier in the previous example.

1. The full load resistance is

$$R_L=\frac{300}{100\times10^{-3}}=3{,}000 \text{ ohms}$$

Plot points for $R_L=5{,}000$, 7,000, and 15,000.
For R_L of 5,000
$R_{bb}=2(240+5000)=10{,}480$ ohms.
The other values of R_{bb} will be 14,480 and 30,480, respectively.
Values of i_2 are,

$$i_2=\frac{490}{10{,}480}=46.8,\ 33.9,\text{ and } 16.1 \text{ milliamperes}$$

2. From the static characteristic, Figure 1,
$e_b]_{i_2}=28$, 25, and 16 volts
Therefore
$E_2=28+46.8\times10^{-3}\times200=37.4$, 31.8, 19.2 volts

3. The ratios of E_2/e_{max} are 0.0765, 0.065, and 0.039.

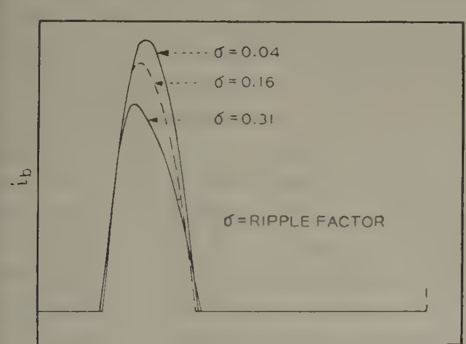

Figure 11. Oscillogram of the plate current pulse in an actual circuit, showing the change caused by an abnormally high ripple factor measured at the filter input

4. The exponent α_c has not been affected by the changing load resistance, inasmuch as R_s is still 200 ohms, so α_c is 1.28. From the curves in Figure 9, the ratios of E_{bb}/e_{max} are -0.73, -0.76, -0.83. This gives values of E_{bb}

$E_{bb}=-0.73\times490=-358$, -372, and -407.

5. Values of I_{DC} are

$$I_{DC}=2I_b=2\times\frac{358}{10{,}480}=68,\ 51.5,\text{ and } 26.7 \text{ milliamperes}$$

Corresponding to these,
$E_{DC}=I_{DC}R_L=68\times10^{-3}\times5{,}000=340$, 360, and 400 volts

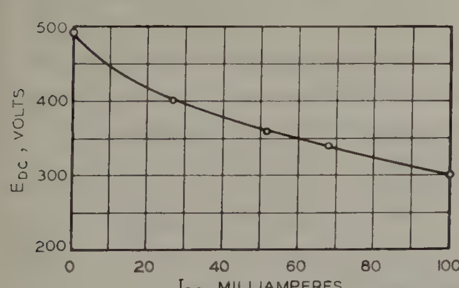

Figure 12. Calculated load characteristic of a full-wave rectifier with capacitor input

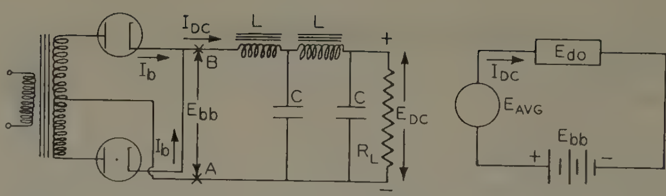

Figure 13. Circuit and equivalent circuit of a full-wave power rectifier, choke input

Utilizing the load point from the first example, and the no load voltage 490, the load characteristic is plotted in Figure 12.

Choke input filters produce a different type of operation, requiring a slightly different approach. The purpose of the choke is to hold the current constant by producing a voltage equal and opposite to all a-c components of the input volt-

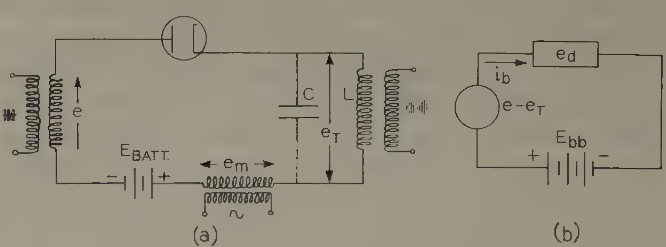

Figure 14. Circuit and equivalent circuit of a simple diode modulator

age. Although no practical inductance does this, the condition is approached closely. The equivalent circuit is, therefore, a d-c circuit with a d-c input voltage equal to the average value of actual sine wave input. Half-wave choke-input filters seldom are used in low-current power supplies, so the following procedure will be applicable to almost any type of choke input filter circuit. Figure 13 shows a com-

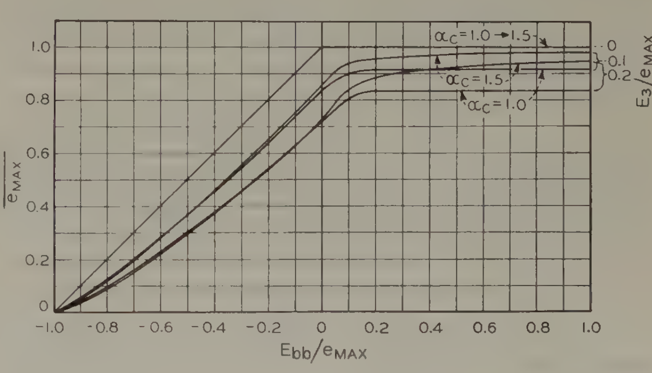

Figure 15. Calculated static modulation characteristics of the simple diode modulator

monly used circuit and its equivalent circuit. Because the net applied voltage is a rectified sinusoid minus all of its a-c components, each tube conducts for exactly half of a cycle, and the current in each tube is the constant value I_{DC}, which is the same as the total output current. This is true if the ripple is assumed negligible. However, even if it is not, the peak voltage occurs at a time when the ripple is just about to pass through zero, making the actual tube current at that

instant I_{DC}. From the equivalent circuit

$$e_{max}=\frac{E_{avg}}{0.637} \tag{11}$$

or the substitute

$$e_{max}=[E_{b0}+I_{DC}R_s-E_{bb}]\frac{1}{0.637} \tag{12}$$

where E_{b0} is the voltage on the static tube curve at the point I_{DC}, and E_{bb} is defined in equation 10. The quantity R_s in the choke input filter circuit is the d-c resistance of the secondary winding only, because of the current pulse shape. This is approximately 125 ohms.[2] Both the forward and backward solutions of the circuit are so simple that no example is given here.

THE DIODE MODULATOR

Either diodes or copper oxide rectifiers can be used in the circuit of Figure 14*a* to produce modulation. Because the tank circuit responds only to the fundamental a-c component of the plate current, the output voltage for the unmodulated condition is sinusoidal, and a half cycle out of phase with e. Thus, e minus e_T can be combined to form e' of the equivalent circuit in Figure 14*b*. Because of the slow rate of varying the modulation voltage e_m, it can be added to the battery voltage to form an effective E_{bb}. The series resistance of all units in the circuit except the tank are added to the tube to form the combination unit. The solution of this circuit is very nearly like that for the power rectifiers, but the results are plotted to show the static modulation characteristic (Figure 15), from which much of the operation can be deduced in terms of circuit parameters. The derivation is given in Appendix IV. To use the curves, the following procedure is recommended. Find i_s from

$$i_s=\frac{e_{max}}{Z_o} \tag{13}$$

where Z_o is the tank-circuit impedance at the tuned frequency. Obtaining a value of $e_b]_{i_s}$ on the static tube curve at the point i_s,

$$E_s=e_b]_{i_s}+i_sR_s \tag{14}$$

where R_s does not include the impedance of any tank circuit. The curves now can be utilized by assuming values of E_{bb}/e_{max} for enough points to plot the static modulation characteristic.

OTHER APPLICATIONS

With modifications, this method can be used to solve triode as well as other diode circuits. The combination of the tube and series resistance reduces the complexity of power series solutions of class *A* circuits considerably. All gas diode problems can be solved by the equations given, if the constant tube drop is used instead of e_b, and α_c is considered to be unity.

Appendix I

To obtain the relationship plotted in Figure 5, take two points on the static tube characteristic. Then

$$\frac{i_{b2}}{i_{b1}}=\left(\frac{e_{b2}}{e_{b1}}\right)^{\alpha_s}=\left(\frac{e_{d2}}{e_{d1}}\right)^{\alpha_c}$$

where e_{d2} and e_{d1} are points on the combination characteristic obtained by adding to e_{b2} and e_{b1} the iR_s drops (Figure 4). Substituting for e_{d2} and e_{d1}

$$\left(\frac{e_{b2}}{e_{b1}}\right)^{\alpha_s/\alpha_c}=\frac{e_{b2}+i_{b2}R_s}{e_{b1}+i_{b1}R_s}$$

Rearranging

$$\frac{R_s}{R_{T_2}}=\frac{\left[\frac{e_{b1}}{e_{b2}}\left(\frac{e_{b2}}{e_{b1}}\right)^{\alpha_s/\alpha_c}-1\right]}{\left[1-\left(\frac{e_{b2}}{e_{b1}}\right)^{\alpha_s(1/\alpha_c-1)}\right]} \tag{15}$$

where R_{T_2} is e_{b2}/i_{b2}. Upon close examination this equation seems to give an impossible result, for no particular value of R_{T_2} has been specified. Actually, α_c is not a constant; but if R_{T_2} is taken at the high point on the curve used, equation 15 will hold and α_c is practically constant. If e_{b2}/e_{b1} is taken as 4, the proper accuracy is obtained, and

$$\frac{R_s}{R_{T_2}}=\frac{\left[4^{\left(\frac{\alpha_s}{\alpha_c}-1\right)}-1\right]}{\left[1-4^{\alpha_s\left(\frac{1}{\alpha_c}-1\right)}\right]} \tag{16}$$

Equation 16 is plotted in Figure 5.

Appendix II

The set of curves plotted in Figure 8 is the solution of the following equations. From the equivalent circuit,

$$e_{max}+E_{bb}=e_{dmax} \tag{17}$$

Elimination of e_{dmax} is obtained by

$$e_{dmax}=E_{db}\left(\frac{i_{bmax}}{I_b}\right)^{1/\alpha_c}$$

which is taken from equation 4. Substituting into equation 17 and rearranging,

$$\frac{E_{db}}{E_{bb}}=\left(\frac{e_{max}}{E_{bb}}+1\right)\left(\frac{I_b}{I_{bmax}}\right)^{1/\alpha_c} \tag{18}$$

which is plotted in Figure 8.

Appendix III

The curves in Figure 9 are obtained in a way very similar to those in Figure 8. Starting with

$$e_{dmax}=E_2\left(\frac{i_{bmax}}{i_2}\right)^{1/\alpha_c}$$

and

$$i_2=\frac{e_{max}}{R_{bb}}=-I_b\frac{e_{max}}{E_{bb}}$$

their substitution into equation 17 gives

$$e_{max}+E_{bb}=E_2\left(-\frac{i_{bmax}}{I_b}\frac{E_{bb}}{e_{max}}\right)^{1/\alpha_c}$$

Finally

$$\frac{E_2}{e_{max}}=\left(1+\frac{E_{bb}}{e_{max}}\right)\left(-\frac{I_b}{i_{bmax}}\frac{e_{max}}{E_{bb}}\right)^{1/\alpha_c} \tag{19}$$

Appendix IV

For the modulator circuit, the curves are arrived at in almost the same way. Equation 17 is rewritten

$$e_{max}-e_{Tmax}+E_{bb}=e_{dmax} \tag{20}$$

As before,

$$e_{dmax}=E_3\left(\frac{i_{bmax}}{i_3}\right)^{1/\alpha_c}$$

and

$$i_3=\frac{e_{max}}{Z_0}=\frac{e_{max}}{e_{Tmax}}\,I_{p1m}$$

where I_{p1m} is the peak value of the fundamental current component that produces e_{Tmax} (see equation 5). Substituting into equation 20,

$$\frac{E_3}{e_{max}}=\left[1-\frac{e_{Tmax}}{e_{max}}+\frac{E_{bb}}{e_{max}}\right]\left[\frac{I_{p1m}}{i_{bmax}}\;\frac{e_{max}}{e_{Tmax}}\right]^{1/\alpha_c} \tag{21}$$

To find the current ratios, a modified form of equation 6 is

$$\cos\theta_p=-\frac{E_{bb}}{e_{max}-e_{Tmax}} \tag{22}$$

When equation 20 is plotted, e_{Tmax}/e_{max} versus E_3/e_{max} for various values of E_{bb}/e_{max} and α_c, a family of curves results similar to those in Figures 8 and 9. A vertical line drawn on these curves represents a modulation characteristic for any specific e_{max} and Z_0. Various modulation characteristics are plotted in Figure 15.

References

1. Calculation and Design of Class C Amplifiers, F. E. Terman, W. C. Roake. *Proceedings*, Institute of Radio Engineers, volume 24, 1936, page 620.

2. Analysis of Rectifier Operation, O. H. Schade. *Proceedings*, Institute of Radio Engineers, volume 31, 1943, pages 341–61.

Creep Measurement With Wire Gauges

Creep measurement of test specimens by means of *SR-4* bonded resistance wire strain gauges instead of the conventional extensometer is reported by the Canadian Bureau of Mines. This method is said to be simple, accurate, and sensitive, and avoids the problem of attaching cumbersome and inconvenient mechanical devices to test specimens. Gauges can be applied to more than one point, if desired, or they may permit using specimens of more convenient dimensions in some instances. The investigation was limited to measurement at room temperature.

Experimental creep measurements were made with two type *A-3* gauges bonded longitudinally on diametrically opposite sides of the center of the gauge length of specimens. Specimens were machined from sand castings of a magnesium alloy and had an over-all length of 12 inches. The parallel gauge length of 10 inches had a diameter of 0.505 inch. Conventional procedures of cleaning, cementing, clamping, and drying were followed. Moisture-proofing was done with particular care. Dried gauges were coated with a liberal layer of Socony Vacuum Petrosene "A" wax. Strain indicating equipment comprised an *SR-4* portable strain indicator used with a 20-point *SR-4* switching unit. A conventional single lever arm creep machine was used for tests.

Creep measurements were checked by a mechanical extensometer system. A dial indicator was fixed to the creep machine hanger and actuated by a metal platform freely supported by two diametrically-positioned 3/16-inch diameter rods clamped to the lower specimen adapter. Elongation of the specimen separated the machine hanger and lower specimen adapter bar, thus actuating the dial indicator spindle and giving a direct measure of extension in the 10-inch gauge length. Temperature effects were compensated by using bars of the same material as the test specimen. Temperature equilibrium was established by delaying the tests two hours after mounting the specimen. In creep measurements with *SR-4* gauges, room temperature variation was not under rigid control. However, approximately constant temperature was maintained by a thermostatically operated exhaust fan, with maximum fluctuation less than ±2 degrees centigrade from 21 degrees centigrade.

Creep loads of 6,500 to 15,000 pounds per square inch were applied gradually over a period of minutes, elongation readings being taken immediately before and after applying the load to show the initial deformation. Tests lasted 1,000 hours and sufficient strain readings were recorded to define strain-time or creep curves. In some instances prestress loads were applied to specimens after reaching equilibrium conditions in the creep machine, these loads being applied gradually over a period of several minutes and then slowly removed. Creep loads were applied immediately after removing the prestress loads.

Elongation-time curves plotted with *SR-4* strain gauge data make a smoother curve with less spread than those obtained with the mechanical extensometer, test showed. However, since the tests were a preliminary study, the results are not regarded as proof that room temperature creep can be measured under all conditions by this technique. They indicate only the possibility of using these gauges for creep measurement. An important factor in applying *SR-4* strain gauges is the stability of the gauges themselves under conditions of constant load. Tests have indicated that a creep of the order of 35 micro-inches per inch during the first 700 hours (with, probably, 75 per cent of this in the first hour) may be expected in gauges of the type used when constant strains of 2,400 micro-inches per inch are present at room temperature.

Protection of the Airplane Main Bus

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THE LARGE INCREASE in installed power of the airplane electric system since just before World War II, and the greater dependence which is placed on it for safe operation of the airplane, have directed much thought to the subject of system protection. As a result of this, methods and equipment are now available for effective protection of the generator circuits up to the main bus. In most cases this protection makes use of the current-balance principle for detecting ground faults. Generator overvoltage protection usually is included also. Equipment for protection of load feeders has not kept pace, in general, with the growth of the system, and the subject of main bus protection practically has been neglected. Several means are available for increasing the safety of the main bus, but there is need for development of better bus protection methods and devices.

PROGRESS IN BUS PROTECTION

The first cardinal principle of bus protection is to minimize the exposure to damage. From this viewpoint the wing-to-wing bus which was used widely in most wartime airplanes, and is still in use in some postwar designs, is hazardous. Although it may show some weight economy, it runs through an area adjacent to fuel lines and tanks, hydraulic lines, and mechanical control cables, and is in a hot zone when thermal wing deicing is used. This area also is subjected to considerable vibration. Under combat conditions, this bus is extremely vulnerable to missile damage. If, however, the bus is concentrated in the center section, the generator feeders which have to run through the wing section may be protected fairly well by available methods.

Much can be done to reduce the vulnerability of a bus by careful attention to arrangement and insulation so that foreign objects such as loose washers and small tools cannot create a fault. At the present time, the use of bus compartments made entirely of insulating material such as a glass fiber laminate is being considered seriously. Proper location and shielding of any metal attachment fittings will prevent possible contact with the bus. Contactors located inside the bus compartment should not have their frames grounded, and the necessary control coil ground connections should be made with small-gauge wire which can burn clear in case of an internal breakdown in the contactor.

The construction of an equally safe 3-phase bus compartment presents more difficulty because of the dual danger of phase-to-phase and phase-to-ground faults and because of the unavoidable crossovers resulting from connections to the bus. The use of solid noncombustible insulating barriers between phases and at crossovers is good practice. The crossover problem becomes simpler if the three phases are stacked or staggered in depth.

While the use of an effective thickness of armor to protect the bus against missile damage is extremely unattractive from a weight standpoint, it is sometimes possible to obtain a certain degree of flack protection by a suitable choice of location with respect to heavy primary structures such as wing spar caps.

If it is assumed that a means is available for isolating a faulted bus section, it is obvious that the bus must be arranged in two or more sections to obtain any benefit in continuity of service. In a commercial airplane, the sections may be all in one compartment with suitable barriers. In a combat airplane, however, the sections should be in separate compartments, well dispersed to minimize the chance of simultaneous damage. The bus tie conductors should be run in multiple, with fusible limiter protection at each end of each conductor. A ring-connected configuration provides maximum safety because the loss of one section still leaves the majority of the system intact.

With all or nearly all of the generators in operation somewhat above their minimum speed, the fusible limiters perform fairly well as automatic isolation means for a bus fault, especially if there are shunt motors on the line to assist in developing fault current. As the generating capacity is reduced by combat damage, or for other reasons, the fault clearing time becomes longer. It easily may reach the marginal time in which heavy motor loads become stalled, in which case the system voltage may be unable to recover unless some of the motor loads are disconnected manually.

Because of the imperfect performance of limiters for main bus protection, other faster and more selective means are needed for combat airplane systems. One method which has been proposed would use a metallic bus compartment which is insulated from ground except for a path through low impedance trip coils on the bus-tie circuit breakers. Fusible limiters in the tie conductors still are needed as backup protection in case of missile damage to the circuit breakers or the tie conductors where they leave the box.

Differential-current bus protection for the a-c system is impractical for airplane use because of the increase in exposure area caused by the current transformers and relays and because of the vulnerability of the control wiring. For the d-c systems it is conceivable that an arrangement of directional overcurrent relays might be devised to detect a bus fault and clear it by means of bus-tie circuit breakers. Further study along this line, with attention to nuisance-trip and vulnerability factors, is suggested.

Digest of paper **48-203,** "Protection of the Airplane Main Bus," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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The Copper Oxide Rectifier

More than 25 years have passed since the discovery of the properties of copper oxide for rectifying alternating current. During the intervening time much has been learned of the characteristics of the rectifier, and improved manufacturing methods have made possible a continually widening circle of application. From small-current low-voltage rectifiers, applications have grown to include extremes in voltage and current, small rectifiers for use in instruments, and voltage limiters and modulators for use in communication work.

DURING a quarter century the copper oxide rectifier has enjoyed a steady increase in the number of applications and the quantity produced and used. The rectifier has a very wide range of applications, both from the standpoint of types of service and from the standpoint of size and capacity. It has been used in applications from radio detection and instrument rectifiers to power rectifiers. It has found many auxiliary uses which are based on the voltage or current characteristics of the units, such as the absorption of energy in magnet coils and the snubbing of relays, the control of pick-up time and release time of relays, click reducers in telephones, and polarization of circuits. For these purposes the units have varied in capacity from a few microamperes, in disks that are only 0.03 inch in diameter, to currents of 25,000 to 100,000 amperes in plating rectifiers, and from microvolts to 1,500,000 volts in rectifiers used for radio detection or instruments at one extreme to voltages for experiments in atomic physics at the other extreme. The sizes of the units vary from vest-pocket editions that contain only a few milligrams of copper to units that weigh many tons. The power capacities vary from microwatts to kilowatts. The consumption of rectifiers during the last few years may be indicated by the estimate that the amount of copper used is between 1,500 and 2,000 tons per year. Without special provision for ventilation 2,000 tons would correspond to approximately 500,000 kw of capacity per year. This capacity is very much increased by the fact that many of the units are provided with forced ventilation, so it can be assumed this estimate is conservative.

DISCOVERY AND EARLY DEVELOPMENTS

The first discovery of the rectifying phenomenon that exists between cuprous oxide and the copper on which it is formed was made in November 1920, and the first practical use of the rectifier was made in 1924.

The discovery was a by-product of another investigation, which at that time was of interest in railway signaling. There existed among railway signal engineers a conviction that relays with moving parts could be improved upon by substituting something that would function in the same way without the movement of parts and without contacts that had to be closed and opened mechanically. The obvious procedure was to study all the different physical devices which had impedances that could be changed at will, with the hope that by the use of such devices and by changing impedances from high to low and vice-versa as required, it would be possible to provide the equivalent of opening or closing an electric circuit by means of contacts. In this effort a study was made of the use of vacuum tubes, gas-filled tubes, light sensitive cells, heat sensitive cells, and variable reactors in circuits that could be substituted for the standard signaling circuits using electromechanical relays. It was found possible on paper to set up such equivalent circuits and many of them were drawn in detail.

Light sensitive cells seemed at one time likely to be the most practical, at least if they could be made with a very low illuminated impedance. The two light sensitive materials that seemed most likely to be useful were selenium and cuprous oxide. Selenium seemed less promising because its behavior up to that time had been found in the laboratory to be very erratic, and to depend on many conditions of heat treatment. Cuprous oxide, however, had been found to be more consistent in its behavior.

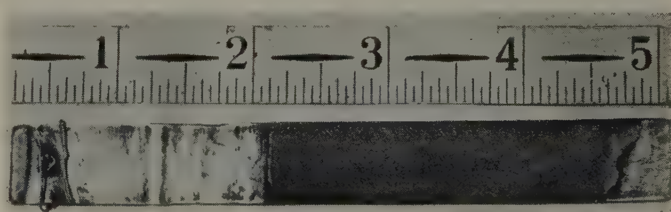

Figure 1. The first copper oxide rectifier

It was realized that in order to get a cell of sufficiently low impedance to provide a circuit to energize lamps or other equipment, it would be necessary to use a path in the cuprous oxide which is short and of great cross section, since cuprous oxide is a semiconductor of high resistance compared to metals. This consideration led to the conclusion that it would be necessary to conduct the useful current

Based upon the following papers presented during the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948:

"Twenty-Five Years of Copper—Copper Oxide Rectifiers" (48-66), by L. O. Grondahl (F '47), Union Switch and Signal Company, Swissvale, Pa.

"Mechanized Methods of Manufacture of Copper Oxide Rectifiers," by E. A. Harty (M '36), General Electric Company, Lynn, Mass.

"Copper Oxide Rectifiers in Railway Signaling," by G. W. Baughman (M '45), Union Switch and Signal Company, Swissvale, Pa.

"Industrial Applications of Copper Oxide Rectifiers," by I. R. Smith (A '43), Westinghouse Electric Corporation, Buffalo, N. Y.

"Copper Oxide Rectifiers in the Instrument Field," by F. X. Lamb (M '44), Weston Electric Instrument Corporation, Newark, N. J.

"Copper Oxide Varistors in Communications Circuits," by M. Y. Priessman, Bell Telephone Laboratories, Inc., New York, N. Y.

across a thin sheet of cuprous oxide. Cuprous oxide is a brittle material, and would be difficult to produce and to use in thin sheets. This led to the very fortunate expedient of producing the cuprous oxide on a sheet of copper by oxidation and stopping the oxidation when there was still enough copper left to serve as a support for the sheet of cuprous oxide, and at the same time to serve as a contact to one side of the semiconductor.

The first unit, shown in Figure 1, was made by placing strips of copper in a nichrome furnace operated at temperatures between 900 and 1,000 degrees centigrade and oxidizing for approximately an hour. Since it was feared that rapid cooling would crack the oxide, the cooling after oxidation was made slowly. During the cooling a certain amount of cupric oxide formed on the surface of the cuprous oxide. The unit was prepared for the photoelectric experiment by breaking off the cuprous oxide at one end of the strip to make it possible to make connections with the copper. The cupric oxide on the surface was ground off on an emery wheel, and a contact was made to the free surface of the oxide by laying a piece of lead against it and pressing the surfaces together by means of a clamp.

The unit then was put in an ordinary Wheatstone bridge circuit to determine its resistance and to determine the effect of illumination on that resistance, with the hope that illumination would drop its normally high resistance to such a value that reasonable amounts of current could be passed through it without the use of excessive voltages. In the Wheatstone bridge the unit had a resistance of 400 ohms, and the illumination of the unit had no observable effect on its resistance. This seemed strange so the experiment was repeated under varying conditions for several days. During this experimentation it was found that sometimes the resistance as shown by the bridge was 400 ohms, and at other times it was 1,200 ohms. The existence of these two definite values of resistance was a puzzle until it was discovered that the resistance depended upon the polarity of the battery used to energize the Wheatstone bridge or similarly on the way in which the copper oxide unit was connected into the Wheatstone bridge. This immediately looked like a rectifier, but it was not realized fully at first that even such a ratio might be useful in some rectifier applications. The unit was laid aside for a while on account of the urgency of the original problem, namely the finding of a suitable relay without moving parts.

Some months later there arose the need for a rectifier to charge a small *B* battery. There was also needed a rectifier for use on a locomotive in train-control apparatus to operate a d-c relay from an a-c source. In such applications the small rectifiers that were available at that time were not very suitable. There were, for instance, the aluminum wet rectifier, rectifiers using vibrating contacts, and other similar cumbersome equipment difficult to maintain, and difficult to use under any condition and especially so under the conditions existing on a locomotive. It seemed likely that the copper-cuprous oxide combination that had been observed some time before might be developed into a useful rectifier for these purposes, and the attempt was made at once. By the fall of 1921 the rectifier began to show promise. At that time it had been concluded that the practical way to assemble such units and to put many elements in series or in parallel was to make the units in the form of washers and to assemble them on bolts with the necessary connectors and insulators.

In these early experiments there was a bewildering mass of details that had an effect on the result, and on the usefulness of the device. Nothing was known about suitable voltages, current densities, type of copper to use, heat treatments, methods of making contact to the free surface, and many other details. In spite of this the unit became useful partly because the competitive units available at that time were not well suited to the desired applications. By 1924 the first practical installation was made. At that time the rectifier was used in a train-control equipment on the Delaware, Lackawanna and Western Railroad to operate a d-c relay from an a-c supply. The rectifier is still in use in that same application.

The subsequent growth of its usefulness was rapid, and thousands were produced for use in radio *A* battery chargers alone prior to the introduction of vacuum tubes with indirectly heated cathodes.

Growth has occurred in three phases:

1. Development of theory.
2. Improvement in quality of the rectifier and in variety of characteristics and of applications.
3. Steady increase in production.

THEORY

The physical facts that have to be explained may be listed as follows:

1. The asymmetric impedance is found to be concentrated at the junction between the mother copper and the cuprous oxide.
2. When voltages applied approach zero, the resistances in opposite directions approach equality.
3. It follows at once that the asymmetry in resistance depends on the voltage applied, and is not inherent in the unit in its normal stabilized condition.
4. In the low resistance direction and at low voltages the impedance decreases approximately exponentially as the voltage increases. At higher voltages the low resistance becomes nearly constant.
5. In the high resistance direction the impedance increases with increasing voltages up to a very high value at approximately $1^1/_2$ volts beyond which it decreases with increasing voltage at a rate that is nearly linear.
6. It is found that when the areas are substantially equal the rectification always takes place at the junction even when the contact on the free surface is made with copper, so that the cuprous oxide lies between two copper contacts.
7. The last observation in common with many others indicates that the type of contact or junction between the cuprous oxide and the mother copper is quite different from ordinary solid contacts.
8. There is a considerable electrostatic capacity at the junction between the copper and the cuprous oxide.
9. Except for this capacity the impedance in both directions is a pure resistance.
10. The asymmetric response to applied voltages is instantaneous.
11. Illumination of the junction produces a photoelectromotive force.

Suggested theories range from a geometric arrangement of parts through thermoelectricity, electrolytic action, work

functions, the assumption of the existence of an insulating layer, and even a physical separation between the oxide and the mother copper, to a combination of many of these, with the assumption of the presence of an electron atmosphere in the cuprous oxide. A theory that was proposed in 1926, while crude in view of more recent developments in the theory of semiconductors, contains the fundamental element of an electron atmosphere in the cuprous oxide which is also in principle a part of the present theory.

PRACTICAL DEVELOPMENT

The copper oxide rectifier has enjoyed one condition that was ideal for the development of a new tool. At the beginning competitive devices were so unsatisfactory that even the crudest type of copper oxide rectifier found useful applications. It was not necessary, therefore, for the copper oxide rectifier to come into the market at the beginning in its most highly developed form. As the development proceeded, new applications became possible so that there was at all times in the commercial situation encouragement for further development. The novelty of the device was well illustrated by the attitude of the United States Patent Office. It became necessary in the early prosecution of the patent applications to provide evidence in the form of affidavits executed by competent engineers, testifying to the performance of the device.

To develop the process to produce better rectifiers, many conditions, each one of which was capable of almost an infinite number of variations, became important. They include.

1. *Temperature of Oxidation.* The first units were oxidized at a little over 900 degrees centigrade. It was soon found that the temperature of oxidation was important and that usually higher temperatures produced better results so that the temperature of oxidation was increased to 1,000 degrees centigrade, and later to the highest temperature that could be used without deforming the blanks by softening of the copper. Since then it has been found that some coppers give the best results at the highest possible temperature while other coppers give better results at somewhat lower temperatures of oxidation.

2. *Duration of Oxidation.* Obviously from a practical standpoint this should be as short as possible, and it was found practical to reduce it from the one hour that was used in the first units to 13 minutes and sometimes considerably less.

3. *Rate of Cooling.* This is very important in the control of the characteristics of the rectifier and will be discussed in greater detail.

4. *Purity of Copper.* Coppers from all available sources of supply were tried and while all were considered pure copper from a commercial standpoint, it was found that there were great differences among them when used in the production of copper oxide rectifiers. These differences were eventually found to be dependent on the presence of very small amounts of impurity in the copper.

5. *Surface Conditions.* In the early stages of the development, much emphasis was laid on the conditions of cleanness of the surface, and of its degree of roughness. A clean surface still is considered absolutely essential. The mechanical condition of the surface as well as the hardness of the copper are not now considered of great importance.

6. *Thickness of Copper.* The first units were made with copper that was 1/8 inch thick. It was found that when the oxidation takes place on one side only, the copper buckles because of unequal thermal contraction of the copper and the cuprous oxide. At first it was thought that this was important because it was believed that the cuprous oxide would crack when the units were straightened out under pressure. Later, however, it was found that this amount of bending of the units was not important so that it became possible then to reduce the thickness of copper from 1/8 inch to 0.05 inch, and later to 0.04 inch in the large units, and even to thinner sections than that for small units.

7. *Methods of Removing Black Oxide.* On account of the high resistance of the cupric oxide layer which forms during the cooling of the disk from the oxidizing temperature, it became necessary to remove this layer. This was first done by grinding, later by sandblasting and by abrading with emery cloth, and finally by chemical solution. The first chemicals used for the solution of the cupric oxide were sodium or potassium cyanide. This was later changed to the use of mineral acids, which is the present practice.

8. *Methods of Making Contact to the Free Surface of the Cuprous Oxide.* This was considered a very important detail, because the forward resistance of the unit depends on the use of the entire cuprous oxide surface for the conduction of the useful current. It was, therefore, necessary to provide a contact that would reach into the depressions of the mat surface of the cuprous oxide, resulting after the removal of the black oxide. This contact was first made by applying a deformable metal such as lead. It was found that in operation the lead reacted with the cuprous oxide and reduced a part of the compound to copper, which made poor contact under these circumstances and increased the forward resistance. This condition was improved by applying a thin coat of tin to the lead, thereby reducing the reactivity of the material with the cuprous oxide. Later a more continuous contact was made by rubbing carbon or graphite into the surface of the cuprous oxide before applying the front contact. Still later this continuous contact was produced by painting the front surface with a suspension of carbon or graphite. Other methods of making contact have since been developed, such as reducing a portion of the cuprous oxide to copper and then electroplating over the copper with nickel. This produces a very satisfactory contact that is independent of atmospheric moisture, and which has very satisfactory low resistance. Another type of contact that is used on small rectifiers is made by allowing evaporated gold to condense on the cuprous oxide.

9. *Application of Pressure.* In the contacts that depend on a deformable metal for continuity, it is necessary to apply pressure. This is done in the disk assemblies by means of pressure applied by the bolt which holds the assembly together. Rather surprisingly it was found that pressures up to 1, 2, or even 3 thousand pounds per square inch can be applied to the cuprous oxide without injury, provided only that it is fairly uniformly distributed. This pressure has to be maintained during the life of the rectifier, and on account of variations in the length of the bolt and in the thickness of the disks due to temperature changes, it became necessary to apply the pressure through springs or spring washers that could take up such irregularities.

10. *Check of Different Kinds of Impurities in the Copper.* This became a very difficult problem which has been under study since 1921, and is still only partially solved. It is definitely known that some impurities are valuable; for instance, it has been proved on many occasions that copper that contains approximately 0.03 per cent of oxygen is more satisfactory for rectifier production than are coppers with a greater or a lesser oxygen content. Despite earlier beliefs to the contrary, it is probably true that a small amount of either lead or silver is an advantage in most types of rectifiers, but that a larger amount, which may not be more than a few thousandths of one per cent, is definitely injurious. Thousands of experiments over many years have resulted in the acceptance of the following generalizations: Small amounts of metallic impurities increase the resistance of the rectifier in both directions, and may result in an increased stability of the reverse resistance. Nonmetallic impurities decrease the resistance in both directions, and result in a decreased stability of the high resistance, but also in a decreased amount of aging in the low resistance. Both types of materials have an effect not only on the resistance of the cuprous oxide itself, but on the resistance of the junction. The ideal toward which many have striven is to get as pure copper as possible to begin with, and then to add the impurities that are necessary to get the characteristics required.

11. *Operating Voltages and Current Densities.* At the beginning a great deal of experimentation had to be done to determine the appropriate

operating voltages per disk and appropriate current densities. The effect of voltage, current, temperature, pressure, and other conditions on the life of the rectifier and the rate at which they would change with time became problems that have been under continuous observation during the last 25 years. Essential requirements were learned to be

1. The lowest possible forward resistance and the highest possible reverse resistance.
2. Permanence, both in the forward and in the reverse resistance characteristics.

In the search for low forward resistance, the rate of cooling soon was found to have an important effect. It has been found that water quenching for best results has to take place from a definite temperature, and that the length of anneal at this temperature is also very important. Quenching has the effect of reducing the forward resistance by a very large amount without having a corresponding effect on the reverse resistance, so that the rectifying ratio and the quality of the rectifier for most applications is improved. The quenching therefore has become standard practice, except for very high resistance rectifiers for special applications.

To indicate the variations that are possible and the amount of control that is available in copper oxide rectifier production, Figure 2 shows d-c volt-ampere characteristics of three types of rectifiers; one high resistance, one low resistance, and one intermediate. The intermediate type is the kind of rectifier that is commonly in use for power applications such as battery charging, other electrolytic work, and the operation of small motors. The high resistance unit would be especially suitable for use in very high-voltage rectifiers where the current requirement is low. The low-resistance rectifier might find uses where the output voltage requirement is low, say two or three volts, and the current requirement is comparatively high. It will be seen that the difference between the high-voltage rectifier and the low-voltage rectifier is a factor of three or more in resistance both in the high-resistance direction and in the low-resistance direction.

MANUFACTURE

As a result of early studies, manufacturing operations were seen to be suitable for mechanization. In 1927 two laboratory conveyer furnaces were built and used in pilot plant work. The first production furnace was designed and built in 1928 using an endless belt conveyer through the hot zones of the furnace. This was replaced by a chain drive to

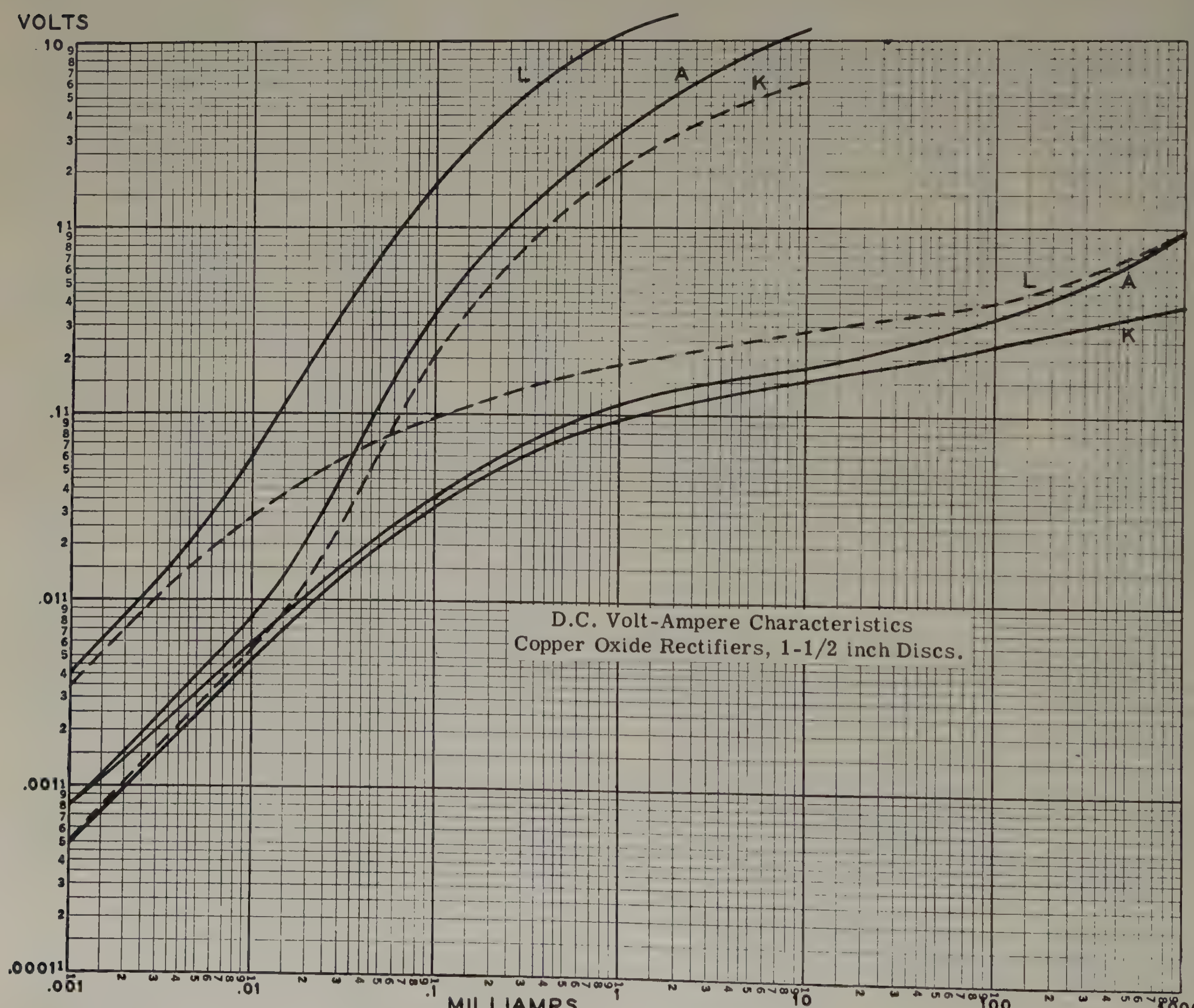

Figure 2. D-c volt-ampere characteristics

obtain better life. This furnace was discarded very shortly thereafter because of high maintenance costs.

During the war a scheme was used in connection with the highly developed roller hearth type of furnace to design and construct a very successful conveyer furnace, the entrance to which is shown in Figure 3. One operator loads and unloads this machine. The furnace has a connected capacity of 250 kw and has been in operation for several years without much trouble.

A conveyer-type plating machine is used in applying a reduced layer of copper to the copper oxide surface and then electroplating over the copper with nickel. This produces a good current collector and makes possible the manufacture of large plate-type rectifier cells as used in high current rectifiers. The cost of mechanization was found to be a sound investment, since it not only reduced the cost of the cells but also improved their quality and narrowed down the electrical differences resulting in closer tolerances between individual cells.

METHODS OF TESTING

The correlation of test results with service behavior has been a very serious problem. In the early stages of the development, all tests were made at two volts, and all rectifiers were rated on the basis of forward resistance at two volts, and the reverse resistance at two volts, or in terms of what was known then as the rectification ratio, which is the ratio between these two resistances.

After some time it was realized that the reading of forward resistance at two volts does not tell the whole story, because the forward voltage in service is usually of the order of 0.5 instead of two, and the reverse voltage in service is often of the order of six volts instead of two. The testing was then changed to the use of 0.5 volt and later 0.5 ampere in the forward direction and six volts in the reverse direction. The tests still were made by taking readings as quickly as possible on the test instruments. Later the reverse voltage used in the tests was raised to ten volts. After many years it was realized that these quick tests did not correlate with the service performance of the disks. Sometimes a rectifier that seemed very unsatisfactory and that would be thrown out on the basis of quick tests was found to be entirely satisfactory in a service test. The problem then was to find a quick test that would correlate better with service performance, and after a great deal of search and much experimentation it was found that a quick test with the units at 70 degrees centigrade correlated very much better with service performance than did the test at room temperature. Even this was not entirely satisfactory, and now is supplemented by a stability test which consists in mounting sample disks in a stack and applying six volts direct current per disk for 24 hours. This test gives very good correlation with service performance, and can be used as a definite indication of the quality of copper oxide rectifier disks.

Life tests are obviously a very difficult problem because the rectifier lasts so long—at least 20 years in power applications and 50 years in some others—that a life test cannot be used as a guide in production. It has been found, however, that there is a definite relation between the life test performance at higher temperatures and the life test performance in service. This correlation is not absolute, but is good enough to give valuable information in a few weeks as to the performance that can be expected by a rectifier in service for many years.

RAILWAY SIGNALING APPLICATIONS

Following the first application of the copper oxide rectifier to train control equipment, the next use and the one accounting for the greatest number of rectifiers used in railway signaling was the charging of line and track storage batteries. Electrolytic and mechanical types of rectifiers previously had been used extensively and a realization of the advantages to be derived from a trickle charged storage battery were being realized.

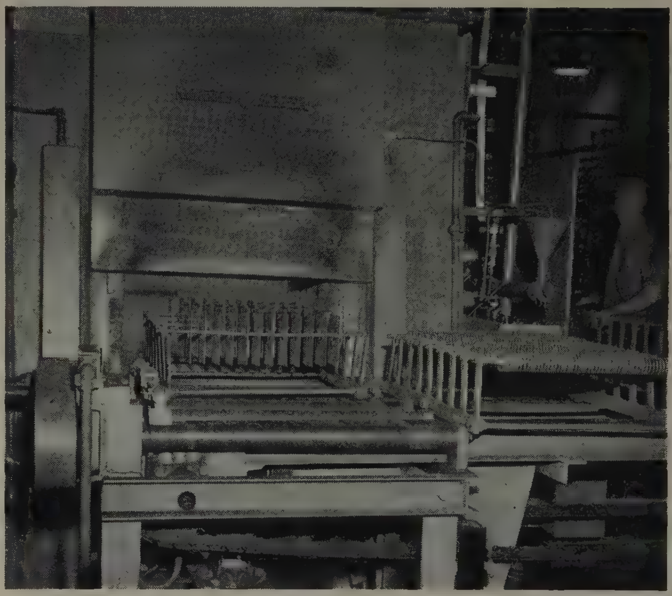

Figure 3. Conveyer-type furnace used in manufacture of copper oxide rectifiers

Just previous to the introduction of the trickle charge method, it was a problem to determine whether it was preferable to use primary batteries and a d-c signal system, or an a-c source of supply and an a-c signal system. The d-c apparatus was somewhat more simple, straightforward, and less expensive than that of a-c power. There was the further problem with a-c power of providing a standby source in the event of failure of the normal power. There were advocates of each type of signal system at that time, and the introduction of the copper oxide rectifier had much to do with the solving of this problem in favor of the d-c system. Another important and contributing factor favoring the extension of the d-c system was the introduction of the coded track circuit with its improved factors of safety relative to the steadily energized d-c track circuit. There are, however, many applications for a-c energy without rectification, such as for track circuit work in electrified territory, and for the cab signal and train-control track circuits.

Retaining the same general system, some railroads prefer to use primary batteries instead of storage batteries, and in this instance a rectifier may be connected so the primary battery is "floated" and normally very little energy is taken from the battery. Reports from service indicate that pri-

mary batteries used in this manner will have a life approximately ten times greater than if the rectifier were not used. The so-called automatic rectifier makes use of the saturable core principle, so the rectifier supplies a current varying directly with the load connected to the battery, thus increasing primary battery life to approximately 20 times greater than if no rectifier were used.

There are several very important signal installations in service where the source of a-c power and the design of the distribution system are so reliable that the rectified energy is used directly for the operation of d-c signal systems. The signal systems in the subways of New York, N.Y., Philadelphia, Pa., and Chicago, Ill., provide outstanding examples of installations of this type. This is also an accepted modern practice used in many of the large terminal interlockings.

The rectifier forms an indispensable part of the coded cab signaling system, the basic principles of which have remained unchanged for 20 years and which now is operating in several thousand cabs.

Rectifiers are used extensively for the protection of contacts operating in inductive d-c circuits and for the provision of a slow release for d-c relays in the line, coding, and storage units of centralized traffic control systems.

POWER AND INDUSTRIAL USES

Power applications began commercially in 1926 with a 1/2-ampere 6-volt battery charger; in 1947 a single rectifier was shipped that had a continuous rating of 16,700 amperes at 6 volts, or 100,000 watts. The steps of growth are indicated in Figure 4. A ceiling was reached at about two kw for self-cooled rectifiers, which was raised somewhat with the introduction of fan cooling but still was limited by the use of small disks. Development of plate-type units brought further increases in size. Of course, installations were made grouping a number of large rectifiers, such as for the continuous tin plating lines, where a single line may use typically 120,000 amperes at 6 volts, or 720 kw.

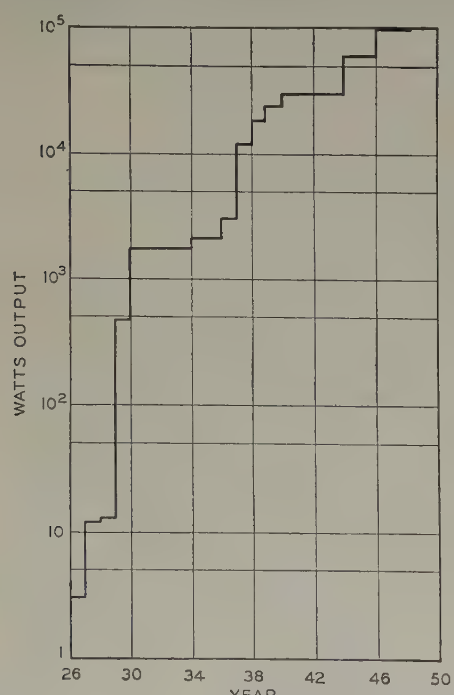

Figure 4. Increase in output ratings of copper oxide rectifiers since 1926

Figure 5 shows the approximate limits reached in combinations of voltage and current output. In general, these

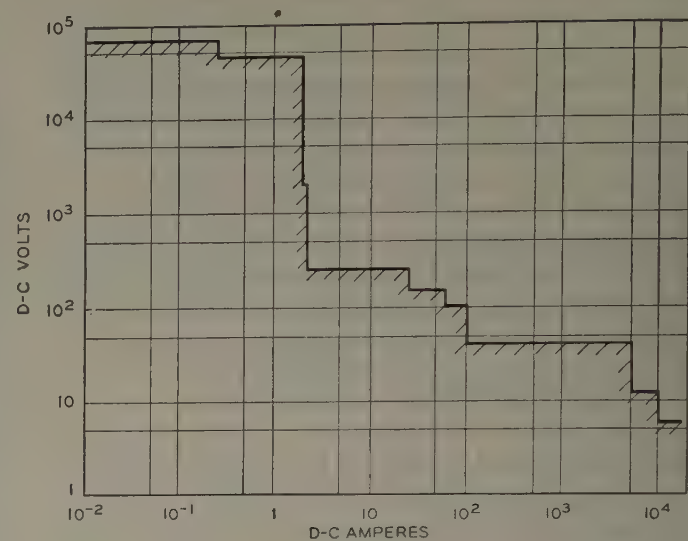

Figure 5. Field of application of copper oxide rectifiers

rectifiers may be classed as high-voltage low-current, low-voltage high-current, and medium-voltage medium-current. While the curve has been located by rectifiers that actually have been built commercially, the boundary is rather vague. Other types of conversion equipment compete for portions of this same field, and the choice of a copper oxide rectifier is not always an economic one; the choice may be made to eliminate moving parts or vacuum tubes, or to reduce maintenance.

Beginning in 1926, rectifiers were considered for such uses as excitation of dynamic loud speakers, *B* battery eliminators, electric hammers, industrial control and brakes, business machines, fire alarm chargers, and communication work. About a year later came cathodic protection and circuit breaker operation. Fan-cooled units began to be used in large quantities in 1935 for motion picture arc projection, and a year later plate rectifiers entered the electric plating field. In 1939 the fast-charger market made its beginning, and high-voltage types of rectifiers were used in radiobroadcasting. In 1940, rectifiers branched out into welding, charging of railway batteries, and anodizing of aluminum. In 1943 a peak was reached in the building of tin plate lines. Figures 6 and 7 show the extremes approached by rectifiers.

INSTRUMENT USES

With the advent of radio in the early 1920's the necessity arose for means of measuring currents in the range below 2 milliamperes, the then prevailing low limit for thermocouple-type instruments. Experiments were made on various crystals such as galena, molybdenum sulphide, and carborundum. When copper oxide rectifiers became

available, they were found far superior to other known means and had definite advantages which rendered them relatively very satisfactory for instrument use. For the order of current measurements intended, namely, one milliampere and less down to as low as 100 microamperes full scale, the size of the rectifier disk required as well as the size of the assembled unit was in keeping with the space available within the instruments, even those of the smallest size. The copper oxide rectifiers when used for current measurements had a voltage drop sufficiently low so as to be considered negligible in most instances.

Actually, the useful range of measurement was extended

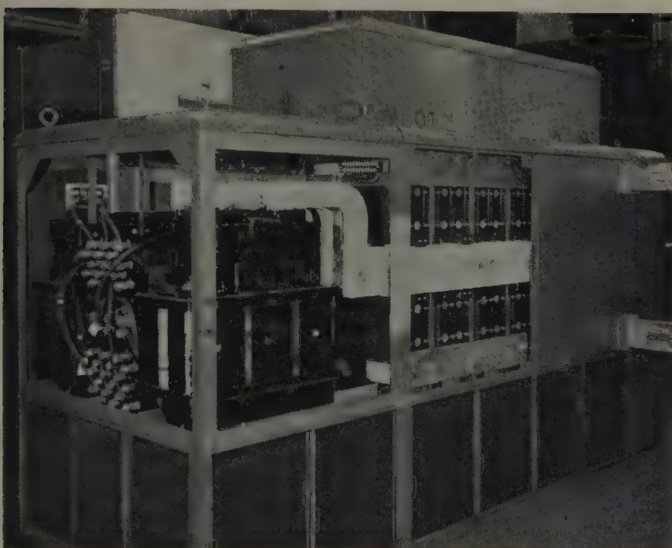

Figure 6. A 100-kw high-current copper oxide rectifier

downward by a ratio of approximately 100 to 1. Whereas formerly the low limit of measurement for the full scale value of an instrument was in the order of two milliamperes, measurements were now possible using rectifier-type instruments down to as low as 20 microamperes full scale and even lower if the more expensive and more sensitive mechanisms were employed.

Acceptance of the copper oxide rectifier in instrument use is illustrated by the output of more than 90,000 units by a single manufacturer in one recent year. One application is shown in the diagram of Figure 8.

USES IN COMMUNICATION

The copper oxide rectifier has been used in the telephone system for 20 years—at first only as a rectifier to supply small amounts of power for charging batteries, for operating relays, to supply plate current for vacuum tubes and the like. A little later as designers became aware of the nonlinear relationship between current and voltage and began to think of the device as a resistance which varied with applied voltage, more subtle circuit uses made their appearance.

Figure 9 shows the voltage–current characteristic of several sizes of copper oxide cells, plotted on a log-log scale so as to exhibit on a single graph, with uniform per cent accuracy, the entire range of useful characteristics. Each diameter of cell is represented by two branches. The flatter curve is the forward characteristic (copper negative) and the steeper one is the reverse characteristic (copper positive). The cell diameters shown (3/4, 3/16, and 1/16 inch) together with a 1/2-inch diameter cell are the sizes commonly used in circuit elements. A line at 45 degrees on this plot represents a constant resistance and it will be noted that the characteristic curves depart but little from a 45-degree slope up to 0.05 volt. As the forward voltage increases the current begins to increase rapidly. A maximum of nonlinearity is reached in the neighborhood of 0.3 volt at which point the current is increasing 50-fold for a 2-fold increase in voltage. As the voltage approaches 1 volt the resistance decreases less and less rapidly and if the voltage be increased on beyond 1 volt the curve approaches a 45-degree line, the ohmic resistance of the copper oxide layer as distinguished from the nonohmic resistance of the junction layer.

These characteristics lead to a simple circuit element known as a voltage limiter. It is seen from the curves that as the voltage in the forward direction increases from 0.1 to one volt the current increases more than 1,000-fold. A "varistor" then may be connected across the input ter-

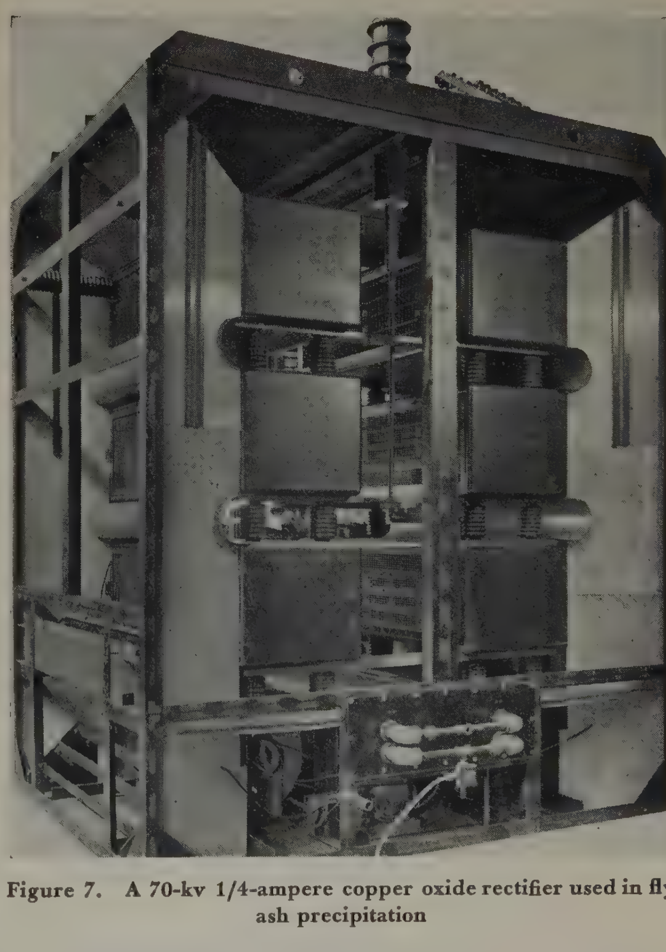

Figure 7. A 70-kv 1/4-ampere copper oxide rectifier used in fly ash precipitation

minals of a network to act as a by-pass when voltages substantially exceed the normal level. In a typical varistor, the resistance is greater than 10,000 ohms for voltages up to 0.1 volt and drops to about 5 ohms at one volt. As the voltage increases above 1 volt the resistance decreases but little. This varistor uses copper to which a small

amount of thallium has been added before the cells are fabricated.

Another important communications application is the copper oxide modulator used extensively in carrier telephone systems. The action of a simple modulator may be explained with the aid of Figure 10. Each of the four arms of the bridge is a copper oxide varistor. The signal or voice voltage appears in mesh R_1. The carrier voltage is designated e_c. The modulated output appears in mesh R_2. When the carrier voltage is of such polarity as to bias the varistor in the forward direction the varistors all will be low in resistance, offering substantially a short circuit. The

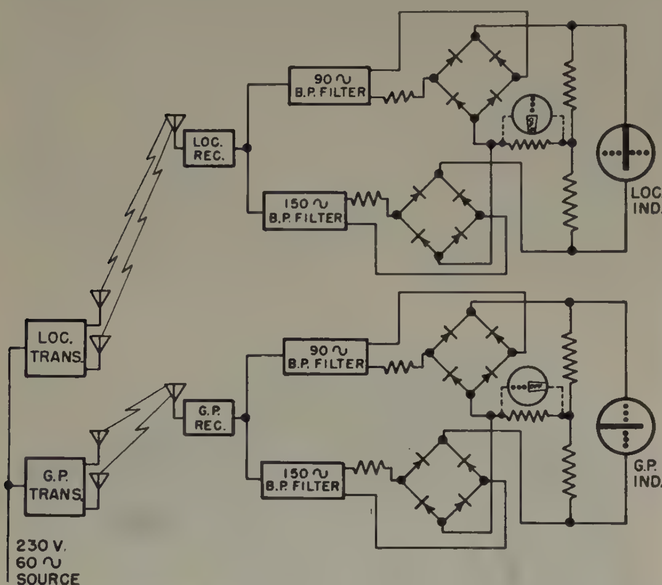

Figure 8. Simplified block diagram of blind-landing transmitting and receiving equipment showing use of copper oxide rectifiers

signal current is thus by-passed through the varistor. When the carrier voltage reverses, the varistors all have a high reverse resistance and the signal current appears in R_2. The action of the modulator under the control of the carrier current may be likened to that of a single-pole switch across

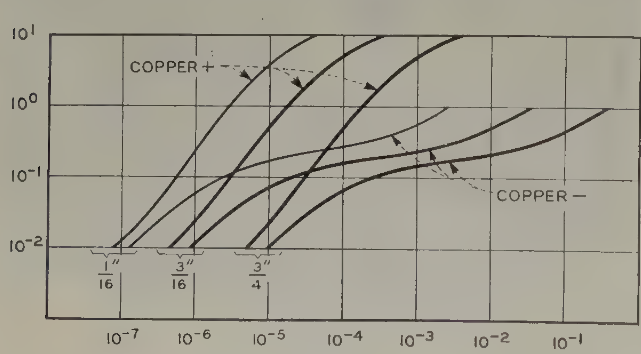

Figure 9. Representative voltage–current characteristics of copper oxide varistors

the line opening and closing at the carrier frequency. Pulses of current appear in R_2 at the carrier frequency, the amplitude of the pulse envelope being proportional to the amplitude of the signal. Unmodulated carrier current is prevented from appearing in R_2 by selecting the four varistors in the arms of the bridge to have characteristics very closely alike so that the bridge is balanced throughout the cycle of carrier voltage. This selection is done by measuring the current and voltage of each varistor cell at as many

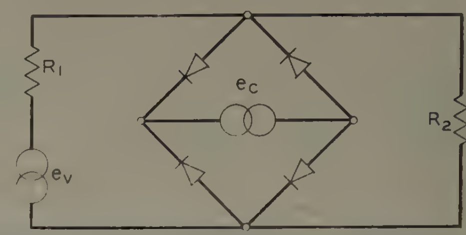

Figure 10. Simple copper oxide modulator

points as need be and then classifying each cell in its proper group. Cells in a particular group are alike to within a few per cent. This requires the use of precision measuring apparatus in constant temperature rooms. In a particular modulator made for a war job the cells were measured and classified in 30 groups at one forward current and then each

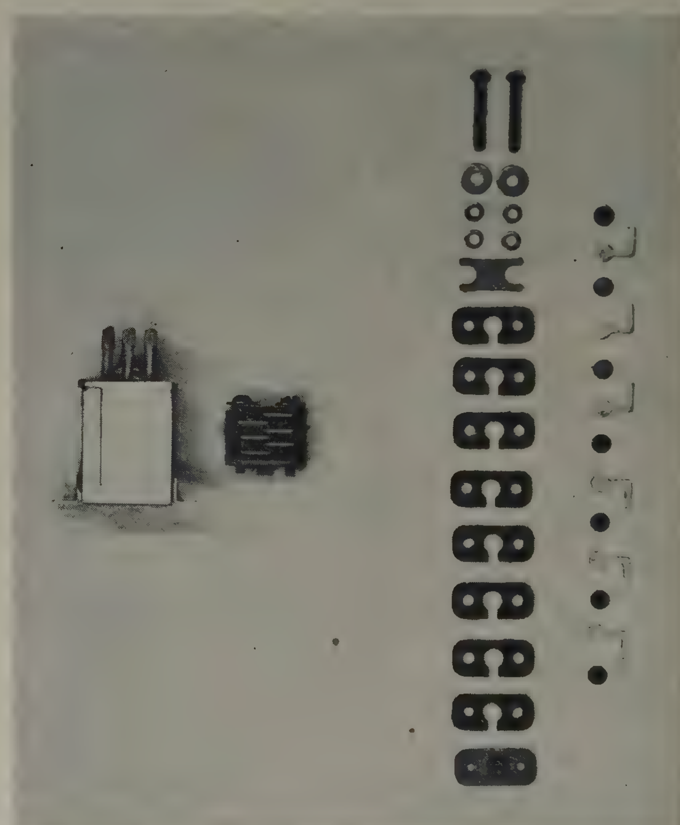

Figure 11. Oxidized copper varistor for use as modulator

of these groups measured at another forward current and reclassified in 30 groups, making a total of 900 pigeonholes in which the cells were finally distributed. Eight cells from a single pigeon hole were then assembled in a double bridge.

These two applications were chosen out of a great number of established uses as illustrative of the kinds of problems that arise in the design of varistor circuit elements and to indicate something of the versatility of this device.

A Polarized Relay as an Aircraft Control Element

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IN ORDER to be suitable for use as an aircraft control element a polarized relay must have characteristics enabling it to meet environmental conditions and performance requirements. The characteristics of a currently used polarized relay having single-pole double-throw normally open contacts, and an inherently well balanced floating armature supported by a torsional spring, may be summarized as follows:

1. *Sensitivity.* Relays have been produced requiring an input of 40 microwatts (1.3 ampere-turns) to close the contacts. Somewhat less sensitivity has been found preferable for many applications.

2. *Operating Speed.* Typical operating speed data are

Resistance		Steady State Voltage on Relay Coil, Volts	Time in Seconds for Contacts to	
Relay Coil	External* Resistance		Close	Open
215 ohms	9 ohms	0.2	0.0155	0.0034
		0.3	0.0078	0.0054
		0.75	0.0016	0.011
215 ohms	119 ohms	0.2	0.007	0.0022
		0.3	0.0035	0.0037
		0.75	0.0012	0.006
215 ohms	Infinite	0.15 to 1.0		0.0005

* External resistance in series with source and relay coil for "closing time" and in parallel with relay coil for "opening time."

3. *Frequency Response.* With minimum operating input resonance conditions exist at approximately 90 and 190 cycles, but are not pronounced. The volt-ampere excitation requirements of a typical relay increase from 0.10 millivolt-ampere at 0 frequency to about 0.25 at 90 cycles, 0.6 at 190, and 450 millivolt-amperes at 600 cycles.

4. *Vibration.* Although the armature is inherently well balanced it is affected somewhat by vibration. Electromagnetic detenting by means of auxiliary field coils which are in series with the load overcomes many of the vibration effects. Secondary relays, with time lag features or circuits, are also helpful.

5. *Overvoltage.* Continuous input of 2.5 watts is permissible. Transient input of 200 watts does not ruin the relay although it will shift the balance point, requiring demagnetization and rebalancing of the magnetic field.

6. *Stray Field Sensitivity.* Unshielded relays can be operated by about 80 amperes in a straight conductor placed in certain positions against the relay.

7. *Arc Suppression.* Resistance–capacitance arc suppressors, if properly designed, help maintain good contact performance and minimize the effects of vibration. On many loads more harm may be done by capacitor discharge current when the contacts close than by arcing at opening. A combination of resistance in parallel with an inductive load and a series *R-C* suppressor across the contacts is quite effective on 28-volt circuits.

8. *Contacts.* Because of low contact pressure and slow armature movement when the polarized relay is used as a contact-making galvanometer in resistance bridge circuits, the contact duty is rather severe. Silver contacts have been found best for general use.

Digest of paper **48-224,** "A Polarized Relay as an Aircraft Control Element," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Royce E. Johnson and **Frank A. Glassow** are both with Barber-Colman Company, Rockford, Ill.

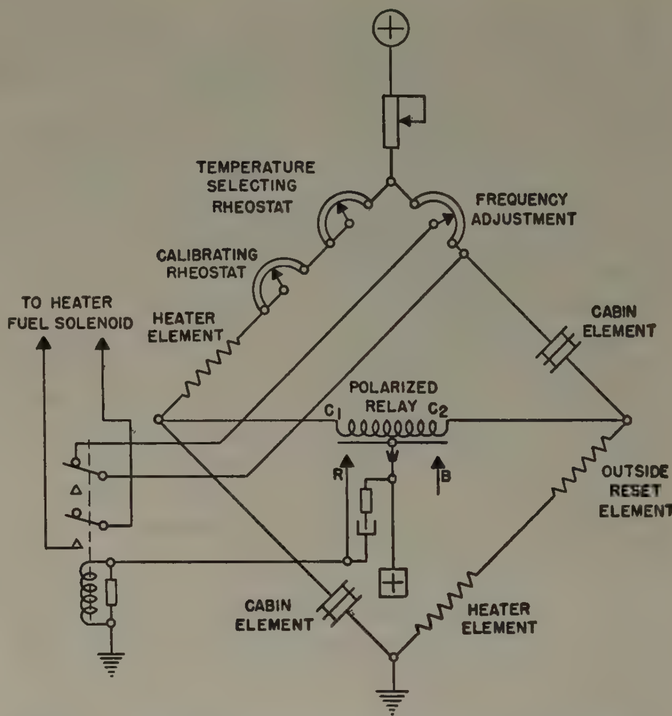

Figure 1. Circuit elements for rapid cycling of an aircraft gasoline heater for cabin temperature control

The field of aircraft control application for this polarized relay includes varied functions which may be classified as

1. Remote positioning—cowl flaps, landing flaps, trim tabs, valves, dampers, nose wheels, cameras, gun sights.

2. Synchronization—landing flaps, trim tabs, flap stabilizer.

3. Temperature control—gasoline heater cycling, cockpits and cabins, carburetor air, engines, wing and empennage surfaces, windshields, camera compartments.

Control systems may be of the 2-position, proportioning, impulse proportioning, or floating control type. Positioning accuracies of ± 1 degree are readily obtainable with systems using potential-dividing slide-wire transmitting and receiving elements. Resistance thermometer bridge circuits, employing thermistor and other temperature sensitive elements, readily permit the modification of control temperatures by changes in outdoor temperature or by manual control from a remote position.

The basic circuit of a control system for cycling a gasoline-burning heater to maintain a prescribed cabin temperature is shown in Figure 1. The cabin elements are made of thermistor disks having a large negative temperature coefficient and are much more responsive than the heater elements, which are composed of fine wire with a positive coefficient.

Line-Fault Locator Using Fault-Generated Surges

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THE PROBLEM of locating faults on high-voltage transmission lines is an old one, but is becoming more important as distances grow longer and more lines are built through isolated mountain and desert areas.

Wartime development of electronic devices and techniques now makes it possible to approach an ideal solution to this problem. Requirements of ideal fault locator are

1. Measurement to be completed before the fault arc is extinguished in order to locate nonsustained faults.
2. Precision of measurement to nearest tower or span.
3. Result indicated directly and instantly without need of developing film or making system analyses.
4. Indication in form readily interpreted by average substation operator or line foreman.
5. Suitable for permanent installation at attended substation or line terminal.
6. Operable without hazard to personnel or service.
7. Simplicity and low cost.

Two systems, designated type *A* and type *B*, have been developed by the Bonneville Power Administration. Both make use of the surges generated by voltage collapse at the fault itself.

In the type-*A* system, the surge from the fault travels to a station at one end of the line, where it starts a calibrated sweep in a cathode-ray oscillograph. It then is reflected from the station bus back down the line to the fault, where it is reflected again, and it again travels to the station. The time interval between the first and second arrival of the surge is measured on the sweep trace. This interval is proportional to the distance to the fault.

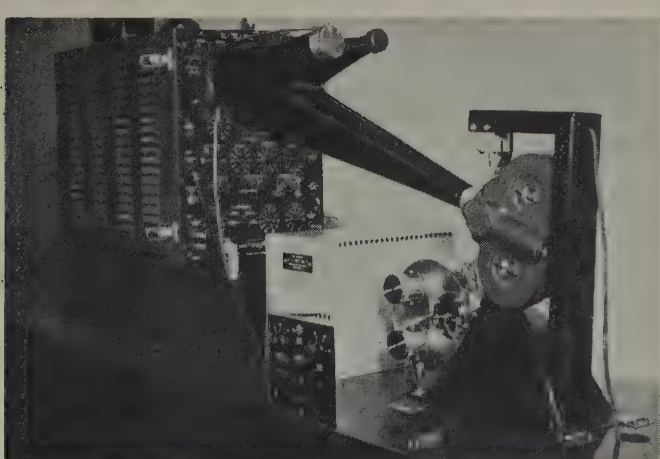

Figure 1. Type-A fault locator

Digest of paper 48-208, "A Transmission-Line-Fault Locator Using Fault-Generated Surges," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE Pacific general meeting, Spokane, Wash., August 24–27, 1948.

R. F. Stevens is chief of the design section and T. W. Stringfield is communication engineer with the Bonneville Power Administration, Portland, Oreg.

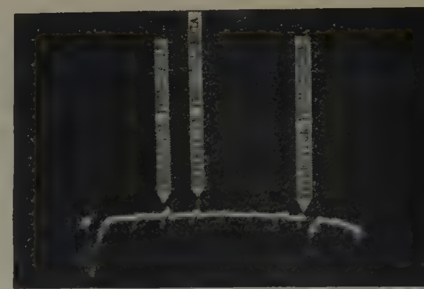

Figure 2. Lightning stroke on Coulee - Columbia 220-kv line

Fault 31.5 miles from Coulee. Fault locator at Spokane. Downward pips are 10-mile range markers. Positive pips are reflections of surge

Figure 1 shows an experimental type-*A* fault locator. Figure 2 shows an oscillogram successfully used to locate a fault caused by lightning on the 72-mile Columbia–Coulee line, obtained with the fault locator at Spokane, Wash. The intervening line between Spokane and Grand Coulee is 82.8 miles long, but all surges traversing this line were delayed equally; therefore, this oscillogram is interpreted as if the device were installed at Grand Coulee.

The type-*B* system makes use of both surges which originate at the fault, and which travel down the line in opposite directions. One arrives at the near end of the line and starts a timing device. The other travels to the remote end. On arrival there, it causes a broad-band radio transmitter to send out a timing pulse, which is received at the near end of the line and stops the timing device. The elapsed time is a measure of the distance from the remote end to the fault. The timing device may be an electronic time interval counter, commercially available, capable of indicating elapsed time in microsecond units up to 999,999. The count is indicated on six banks of indicating lamps arranged in decades. A permanent record can be obtained by adapting a commercially manufactured chart recorder for use with the time interval counter.

The principal disadvantages of the type-*A* fault locator are the need for photography and difficulty in interpreting the oscillograms because of spurious reflections from substation busses on interconnected lines. These are overcome by the type-*B* fault locator. The type-*B* fault locator can be applied economically wherever a broad-band radio link exists between the two ends of the transmission system to be monitored. No perceptible interruption to normal use of the link will result.

The first such actual installation of a type-*B* system will be made during the coming year in conjunction with a microwave radio system recently purchased by the Bonneville Power Administration. This radio system was planned for telephone communication, telemetering, facsimile, relaying, and supervisory control without, originally, any regard to use for fault location. It is suggested that other power utilities who may be investigating microwaves for such uses also may find it advantageous to provide for this quick, accurate, and inexpensive means of fault location.

Mathematics for Engineers—II

Method of Graeco-Latin Squares

H. PORITSKY

In this second part of a 3-part series, a method is described whereby time and effort in examining problems involving a number of variables may be reduced greatly by selecting only those combinations of greatest significance. It has been applied for four, five, and six variables, provided the number of values of each variable is one less than the number of variables.

IN ENGINEERING investigations and laboratory experiments it often happens that the effect which is being investigated, or the performance of the device or of the particular material under consideration, depends upon a great many variables. It is of importance to be able to pick out the significant variables, whose variation will affect the results of the experiment or the performance of the device or of the substance in question, from the insignificant ones whose variation has little if any effect, so as to minimize time and effort in devising experiments and building and testing samples. Added to the difficulty of too many variables is the fact that there are also accidental and random variations, due to quantities which are either unknown or which it is out of the question to investigate, and which thus are termed accidental.

A standard method of testing any one variable consists in varying it only while holding all the others constant. To cover a range of variation of many variables by this straightforward method generally involves far too many tests, unless one is willing to make the assumption that if the variation of one variable x_1 proved of little significance for *one* set of values of the other variables, $x_2, x_3, \ldots$, its variation also will be of little import for other sets of values—an obviously unwarranted assumption.

The method of Graeco-Latin squares enables one to cover a range of many variables in a somewhat systematic fashion with a minimum number of tests. It thus leads to results with the greatest economy of effort, and yields most information for a given number of tests.

To explain this method, suppose there are four variables: x_1, x_2, x_3, x_4. Suppose that three values are taken on by each variable, as shown in the array (1):

$$\left.\begin{array}{llll} x_1: & \mathrm{I} & \mathrm{II} & \mathrm{III} \\ x_2: & A & B & C \\ x_3: & 1 & 2 & 3 \\ x_4: & a & b & c \end{array}\right\} \qquad (1)$$

If each value of each of these variables were employed and combined with every value of every other variable one would have to carry out altogether $3^4 = 81$ samples or tests. By contrast the Graeco-Latin square method utilizes only a total of 9 combinations of values shown in Table I.

It is clear from this table just what nine combinations of values of each of the four variables are employed. Thus, if the values displayed in expression 1 proceed in increasing numerical order, the upper left-hand corner of Table I corresponds to the smallest value of each of the four variables, $x_1 = \mathrm{I}, x_2 = A, x_3 = 1, x_4 = a$.

It will be noted that each element of the first row of Table I contains the value A, each element of the second row the value B, each of the third row the quantity C. Likewise, each element of the first column contains the value I, each element of the second column the value II, each element of the third column III. In this way the samples picked are distributed evenly among the values of the first two variables x_1, x_2 in the array (1), each value of x_1 occurring once and only once with each value of x_2. Likewise, they also can be shown to be uniformly distributed in all four variables x_1, x_2, x_3, x_4 in that each of the 12 values in the array (1) occurs combined once and only once with each of the 9 values of the other variables occurring in the array.

Table I. Combinations of Values of Four Variables

	I	II	III
A	$1a$	$2b$	$3c$
B	$2c$	$3a$	$1b$
C	$3b$	$1c$	$2a$

Similar Graeco-Latin squares have been constructed for 5 and 6 variables provided that the number of values of each variable is one less than the number of variables (that is, 4 and 5). These squares are shown in Table II and Table III.

They, too, have the same property that as many elements are assigned to each value of each variable as to any other value of the same variable and each value of each variable occurs once with each value of every other variable.

Table II. Combinations of Values of Five Variables

	I	II	III	IV
A	$1a\alpha$	$2b\beta$	$3c\gamma$	$4d\delta$
B	$2c\delta$	$1d\gamma$	$4a\beta$	$3b\alpha$
C	$3d\beta$	$4c\alpha$	$1b\delta$	$2a\gamma$
D	$4b\gamma$	$3a\delta$	$2d\alpha$	$1c\beta$

Table III. Combinations of Values of Six Variables

	I	II	III	IV	V
A	$1a\alpha V$	$2b\beta W$	$3c\gamma X$	$4d\delta \Upsilon$	$5e\epsilon Z$
B	$2c\delta Z$	$3d\omega V$	$4e\alpha W$	$5a\beta X$	$1b\gamma \Upsilon$
C	$3e\beta \Upsilon$	$4a\gamma Z$	$5b\delta V$	$1c\epsilon W$	$2d\alpha X$
D	$4d\epsilon X$	$5c\alpha \Upsilon$	$1d\beta Z$	$2e\gamma V$	$3a\delta W$
E	$5d\gamma W$	$1e\delta X$	$2a\epsilon \Upsilon$	$3d\alpha Z$	$4c\beta V$

H. Poritsky is with the General Electric Company, Schenectady, N. Y.

After the experiments have been designed, or the apparatus built, and tests carried out in accordance with the squares just described, and measurements of the quantity of interest obtained, one proceeds to analyze them as follows. Consider, say the variable x_1 whose values I, II, III, correspond to the columns of the three tables. First the means X_{I}, X_{II}, X_{III}...of the values of each column are found; then one obtains the over-all mean $\overline{X}$, which is also the mean of the means of the individual columns. Next one calculates the variance σ_2 of the difference of the column mean and the over-all mean, by means of

$$\sigma^2=\left[\sum_{i=\text{I, II}\ldots}(X_i-\overline{X})^2/(n-1)\right] \tag{2}$$

where n is the number of columns. In general, the variance σ^2 of a population is the square of its standard deviation σ:

$$\sigma=\left[\sum_{i=1}^{N}(X_i-\overline{X})^2/N\right]^{1/2} \tag{3}$$

However, for a sample of N members taken for a large population, under the normal law of distribution, the standard deviation from the mean of the sample is somewhat higher than for the population as a whole, and is obtained by replacing N in equation 3 by (N-1):

$$\sigma_{sample}=\left[\sum(X_i-\overline{X})^2/(N-1)\right]^{1/2} \tag{4}$$

It is now essential to find out whether the variance obtained is significant or whether it is merely accidental. For this purpose it is advisable to repeat the experiments and observe how closely individual entries repeat themselves. More precisely, say for the case of four variables, if the experiments are repeated once, the deviations of each set of values in Table I from their mean are obtained and the variance (of these deviations) is computed

$$\sigma_a^2=\left[\sum(X-\overline{X})^2/n_a\right] \tag{5}$$

where now $n_a=9$ (due to the nine entries in Table I).

To find whether the variable x_1 is significant or not, one now compares the variance σ^2 in the means of the columns with the accidental variance σ_a^2. Statisticians have worked out several methods by means of which one can decide (to within a certain degree of certainty) whether the first variance σ^2 is significant compared to σ_a^2 or not. If it is, then the variable x_1 is an important variable; if it is not, then the variation of the function in question with x_1 is either too small to be of interest or will be covered up by a random variation due to the impossibility of repeating the results.

One convenient test for significance of variations is given by the "F-test" (see, for instance, reference 1). First, the ratio F of the two variances is found, say always in such a way as to lead to $F>1$. It will be noted that for Figure 1, σ^2 was based on $n=2$ "degrees of freedom," while σ_a^2 was based on $n_a=9$ degrees of freedom—by a "degree of freedom" is meant the number of *independent* values upon which the variance calculation is based; since the deviations $X_i-\overline{X}$ of a set of n values from their mean necessarily satisfies the condition of a vanishing sum, this set possesses n-1 degrees of freedom. The table entry corresponding to these two values for say 5 per cent degree of significance gives an entry $F=8.02$. If the F value obtained from the tests is larger than the table value F then the chances are 95 per cent that the variable x_1 is a significant variable; if not, then within the foregoing certainty x_1 is not a significant variable.

The F test and the tables for it are based upon a Gaussian distribution of random variation.

After the significant variables have been singled by this method from the total number of variables considered, one must proceed with a more detailed exploration of their range so as to find the optimum performance for the device or the substance under consideration.

Two instances may be mentioned where the method of Graeco-Latin squares has been applied in the General Electric Company, one where it is worked very successfully, the other one with rather little success. The first case was in design of a tachometer compensator, the other one in the study of an alloy.

In the tachometer compensator problem which was studied by P. E. Thompson of the works laboratory of the West Lynn Works, it was a question of obtaining the best control of temperature variations of the tachometer. This was accomplished by means of a compensator plate and the following four variables were considered to be the controlling factors: location of the compensator plate, thickness of the plate, electrical conductivity of the drag disk, and thermal coefficient of electrical conductivity of the drag disk. Nine tachometers were built in accordance with Table I and calibration was obtained for them at four temperatures and was investigated by means of the F test. By analyzing the results it was found that the coefficient of thermal conductivity was not an important factor, but the three other factors were significant. Optimum values for them then were determined to yield the least error.

The second instance was an application of Graeco-Latin squares to the study of a 6-component alloy by J. D. Nisbet and Ann Lindberg of the research laboratory at Schenectady. Here the percentages of five of the component elements of the alloy were used as the variables $x_1\ldots x_5$ in question, and alloy samples were prepared in accordance with the square of Table II. However, the analysis of the results showed that it was impossible to pick out any one element as more significant than any other one. Except for indicating that all of the elements were significant, no useful result was thus obtained from application of the Graeco-Latin square method in this case.

Generally, in making up Graeco-Latin squares the values of any one variable are taken to be equally spaced. Thus in the array (1) the values denoted for I, II, and III are equally spaced, and the same applies to the three values of each remaining variable. This need not be the case, however, always.

Examples can be readily constructed where by replacing the original variables by a set of new variables which are functions of the original variables one will obtain significant and nonsignificant variables, when that is not the case with the original variables. However, this is a situation which the method of Graeco-Latin squares is not capable of detecting.

It may be pointed out that if in case, say of four variables, the dependent quantity y is a linear function of the three

variables, say x_2, x_3, x_4, then it is possible not only to separate the significant variables from the insignificant ones, but also to obtain the functional variation of y with x_1 from the column mean of the Graeco-Latin square. As will be noted from Table I, each value of each one of the variables x_2, x_3, and x_4 occurs once and only once in the three elements of each column of Table I. It follows that the column mean will average out the values of those variables, and if the column mean is plotted against the values of the variable x_1, the points should lie on a straight line if there is linearity in x_1 also, or on a curve if x_1 does not enter linearly; discrepancies due to accidental variations also will show up, though with only three values keen judgement is required to decide whether the deviations from a straight line are due to a nonlinear dependence upon x_1 or to accidental variations. Thus, under the assumption of partial linearity, it is possible not only to pick out a significant variable but also to obtain coefficients of variation and the optimum value of the dependent variable. This naturally will occur at one end or the other of the range of each linear variable.

REFERENCE

1. **H. A. Freeman.** John Wiley and Sons, New York, N. Y., 1946. Table 8, pages 170–1.

Standards of Very Small Capacitance

Lack of standardization in capacity measuring equipment often has resulted in losses due to rejection by the purchaser of electron tubes whose interelectrode capacitance was not within the tolerance limits for acceptable performance. The result has been a demand for secondary reference standards of small capacitance. The National Bureau of Standards was requested to establish and maintain a group of primary capacitance standards ranging from 100 down to 0.001 micromicrofarads.

The capacitance values of several small capacitors have been determined by a process of stepping down or of subdivision from larger units, which ordinarily are measured by well-known bridge methods in terms of resistance and time. However, for capacitances from 5 micromicrofarads down it was considered desirable to check the accuracy of the subdivision by the use of absolute standards whose values could be computed from their mechanical dimensions.

In the range from 5 micromicrofarads to 0.1 micromicrofarad the Kelvin guard-ring type of capacitor was used as a primary standard. In this device the high-voltage electrode is supported at a fixed distance from a smaller measuring electrode, which is surrounded by a guard ring to eliminate fringing. The larger electrode is connected to the high-voltage terminal of a bridge and the measuring electrode and guard ring to the ground-potential terminals of the same instrument. Only that portion of the total flux from the high-voltage electrode which reaches the smaller electrode is measured by the bridge and is used in comparing the capacitor with a secondary standard. For precision work an improved design was developed at the bureau in which the guarded electrode and the guard ring, separated by a very small gap, as well as the high-voltage electrode, are flat and polished so that they can be tested readily by optical methods for parallelism, coplanarity, and symmetry. The guarded electrode, or "island," is rigidly and accurately centered in the guard ring by means of a Pyrex-glass collar held firmly in position.

For capacitance below 1 micromicrofarad, a new type of guarded-electrode capacitor was developed for the range from 0.1 micromicrofarad down to 0.001 micromicrofarad on the basis of a design suggested by Doctor F. B. Silsbee of the National Bureau of Standards. In the new capacitor the guarded electrode, instead of being coplanar with the guard ring as in the Kelvin type, is placed at the bottom of a cylindrical well of fixed depth below the surface of the guard. Fringing occurs, depending on the depth of the well, so that only a fraction of the electric flux from the high-potential electrode reaches the measuring electrode. By increasing the depth of the well, the capacitance can be made as small as desired; at the same time the capacitor is of such dimensions that it can be constructed and measured accurately. The construction of the guarded plate and of the high-voltage electrode is identical with that of the guard-ring capacitor.

Formulas for computing the capacitance of both types of capacitors have been derived by Doctor Chester Snow of the National Bureau of Standards on the assumptions that the clearance between the island and the guard ring is infinitely small, that the edges of the hole in the guard ring are not rounded, and that the guard ring and voltage plates extend to infinity. However, measurements on an experimental model have shown that the clearance between the island and the guard ring can be as large as several thousandths of an inch without appreciably altering capacitance, and that the high-voltage plate need extend over the edge of the guard ring for a distance only three or four times the space between the high-voltage plate and the ring.

In addition to the primary standards, several secondary standards have been built. One of these is a decade of noval construction having two units of 0.1 micromicrofarad, two units of 0.2 micromicrofarad, and one unit of 0.4 micromicrofarad. Each unit of the decade consists of a pair of plates, insulated from the housing by mica insulation, together with a metallic blade which is connected to the housing. The individual units are switched out of the circuit by sliding the metallic blades between them. This completely isolates one terminal from the other, making the capacitance of the unit zero. The capacitance of each unit may be adjusted within very close limits by means of a vernier screw which controls the effective distance between plates. The units were adjusted at the bureau to be equal or exact multiples of each other within the limits of sensitivity of a bridge and have held this adjustment for over a year.

A 6-Trace Cathode-Ray Oscillograph

P. L. EDWARDS

TESTING of ordnance often requires the recording of high-speed steady-state and transient phenomena both in the field and the laboratory. The portable multichannel magnetic-string-type oscillograph is admirably suited for recording many signals simultaneously, but does not possess the high-frequency response, the high-input impedance, or the high sensitivity often required.

The Naval Ordnance Laboratory 6-trace cathode-ray oscillograph (*6TCRO*) is a portable general-purpose oscillograph designed to eliminate the aforementioned difficulties. With this instrument it is possible to record six signals and two timing traces simultaneously. Six 2-inch cathode-ray tubes each are driven by a high-gain high-input-impedance d-c amplifier with a flat amplitude response to 40,000 cycles per second. Two additional 2-inch tubes are employed for recording timing signals which are produced internally. The indications of the cathode-ray tubes are recorded on a moving strip of 35-millimeter film.

The power supply consists of electronically regulated 460- and 340-volt supplies and an a-c regulated accelerating voltage supply. The alternating-voltage stabilizer also regulates the filament voltage for the tubes of the first stage in the amplifiers. The power consumption is 500 watts at 115 volts and 60 cycles per second.

Each amplifier has a single-sided input into the first stage, a common-cathode-resistor phase inverter, which drives the second push-pull stage. The second stage drives the horizontal deflecting plates of the cathode-ray tube. Each d-c amplifier has a gain of 8,000, an input impedance of 0.1 megohm, and a frequency response which is flat from zero to 40,000 cycles per second and is down 6 decibels at 100,000 cycles per second. The well regulated power supply, the regulated filament voltage on the first stage, plus a careful selection of tubes, has led to an amplifier relatively free from microphonics and with a spot drift, after a warm up period of 30 minutes, of less than 1/4 inch in 20 minutes.

A means for voltage calibration of the channels is contained within the *6TCRO*. The output of a sine-wave oscillator may be attenuated to any desired value, measured by an internal vacuum-tube voltmeter, and applied to the inputs of the amplifier channels. A switch is provided so that the attenuated output of the oscillator may be fed into the amplifiers without the need for external leads.

For timing purposes, the output of the oscillator is clipped, amplified, and applied to the two timing cathode-ray tubes previously mentioned. The oscillator frequencies, and thus the timing frequencies, may be 40, 200, or 1,000 cycles per second.

Digest of paper **48-217**, "The Naval Ordnance Laboratory 6-Trace Cathode-Ray Oscillograph," recommended by the AIEE instruments and measurements committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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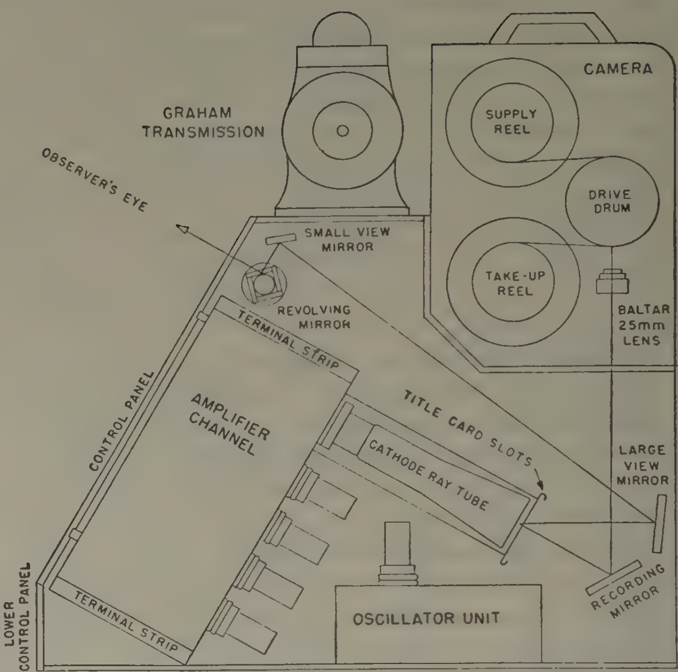

Figure 1. Cross section of the main unit

Figure 1 shows a cross section of the main unit. The light from eight cathode-ray tubes—six for recording and two for timing—is reflected by the recording mirror to a Baltar 25-millimeter focal length lens which focuses the light from the fluorescent spots on the moving 35-millimeter film. For viewing, the light is reflected from the large view mirror to the small view mirror and from there to the rotating mirror which provides a visual sweep if desired.

There are two modes of operation of the moving film camera. In continuous operation 100 feet of film are available for recording at film speeds of 1/3 to 12 feet per second. In drum operation, 10 inches of film are available for recording at speeds of 1/3 to 38 feet per second. The choice of continuous or drum operation depends on these factors:

1. The film speed necessary to resolve the signal.
2. The duration of the signal.
3. The feasibility of synchronizing the signal with the recording period of the oscillograph.

High-frequency response makes possible the recording of short-duration phenomena of the order of 200 microseconds and the pressure–time curves of underwater explosions. The absence of phase and amplitude distortion in the low frequencies also makes possible the faithful reproduction of long duration transients. The high sensitivity of the channels makes possible the recording of the output of some strain gauge circuits without additional amplifiers. The instrument also is very useful in the determination of the time sequence of various complicated phenomena.

13,800-Volt Distribution in the Bunker Hill Mine

LeVERN M. GRIFFITH
MEMBER AIEE

THE BUNKER HILL mine ore body near Kellogg, Idaho, started as a prospect hole high on a mountainside in 1886. Since then the electrical development of the mine has followed closely the technological development of the electrical industry.

The first electric power used in the mine was 225 volts direct current. This was followed by 550 volts, single phase, alternating current; then 2,300 volts, three phase, alternating current, and in 1941 the first 13,800-volt feeder was placed in service.

The decision to use 13,800 volts for the mine primary distribution was made after nearly two years of study and analyzations to determine

1. A design load pattern. How much power, where?
2. The most economical voltage for the design load.
3. The most flexible and efficient distribution system.

The design load for a mine is not a great deal different from that of other industrial plants, except that the load is mostly widely dispersed large units and the load center is continually shifting. Establishing the design load pattern requires the knowledge and experience of the geologists and management as well as the engineers.

The determination of the most economical voltage, conductors and circuit arrangement was made with the aid of the General Electric a-c network analyzer. This analyzation indicated the advantages of a 13,800-volt primary loop with three substations underground; 3,000 kva on the main haulage level; 1,500 kva on the 21 level, 2,200 feet below the main haulage level; and 1,500 kva on the 25 level, 3,000 feet below the main haulage level. The first 3,000-kva part of the loop has been in operation for eight years, with the 21-level 1,500-kva portion in operation since 1944 (see Figure 1). The 25-level substation probably will not be in operation before 1951.

On the basis of May 1948 prices, the complete 13,800-volt mine-distribution system would cost $257,000 installed as compared to $422,000 for a 2,300-volt distribution system of equal capacity. The annual power losses, based on 50 per cent of the design load continuous, at $50 per kilowatt-year amounts to $3,800 for the 13,800-volt system and $7,700 for a comparable 2,300-volt system.

Particular care has been emphasized in the installation of the 13,800-volt equipment to provide secure low resistance grounding, surge protection at all switch points and cable ends, high mechanical and electrical strength at all cable joints, complete metal enclosure of all live parts, and the elimination of condensation in switchgear.

The prospect of working around 13,800 volts underground was at first disturbing to some of the electricians. After a few years of experience with this installation, it is conceded generally that the metal-enclosed 13,800-volt switchgear is much safer to work around than the old open busses and panels at 2,300 volts. The hazards of minimum clearances, high humidity, condensation, and falling rock fragments make metal clad equipment practically mandatory in the Bunker Hill mine.

Digest of paper **48-206**, "13,800-Volt Distribution in the Bunker Hill Mine," recommended by the AIEE mining and metal industry committee and approved by the AIEE technical program committee for presentation at the AIEE Pacific general meeting, Spokane, Wash., August 24–27, 1948. Not scheduled for publication in AIEE *TRANSACTIO /S.*

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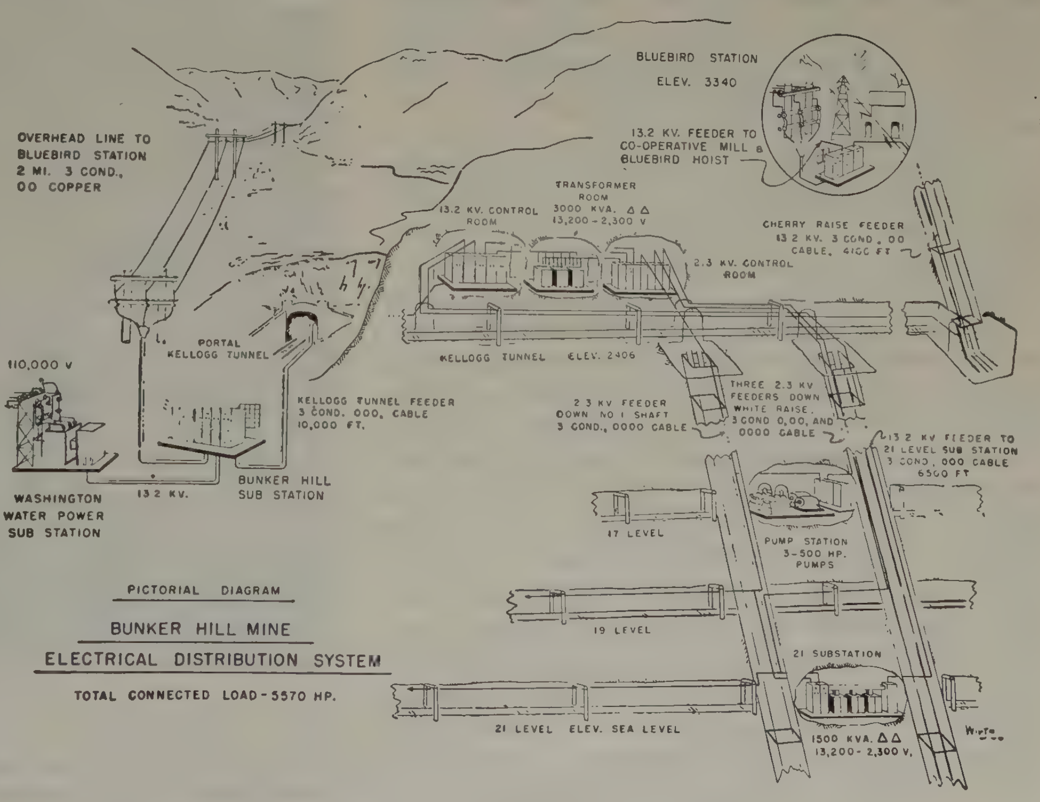

Figure 1. Pictorial diagram of Bunker Hill electric distribution system

Liquid Dielectrics for Transformers

J. G. FORD
ASSOCIATE AIEE

As liquid dielectrics, hydrocarbon oils have many desirable characteristics and one serious disadvantage—the fact that they are combustible. Although not as generally excellent as the oils, the askarels also are suitable for this use and, in addition, are fireproof.

HYDROCARBON OILS when properly processed from crude oil possess all the good properties required in liquid dielectrics for either transformers or circuit breakers. They are inexpensive, relatively abundant, and have long life when treated with due consideration for their characteristics. Possibly the most serious objection to hydrocarbon oils for use in transformers is that they are combustible. Liquid dielectrics known as askarels overcome this fire hazard but do not possess all the excellent properties of oil. They are nevertheless suitable for transformer application.

HYDROCARBON OILS IN SERVICE

Acids Formed by Oxidation. When hydrocarbon oils are heated in the presence of oxygen—a condition often experienced in transformers—they oxidize slowly and objectionable products are formed gradually. In general, these products consist of low molecular weight acids that are soluble in water, higher molecular weight acids that are insoluble in water, and solid oxidation products or sludge that result primarily from polymerization and condensation of intermediate oxidation products. These water-soluble acids, along with moisture, are the chief causes of internal corrosion. Oil soluble acids are not particularly harmful but do have an influence on the power factor of oils. Solid oxidation products interfere with heat transfer because of their precipitation into critical areas.

There are intermediate oxidation products, for example, peroxides, that are thought to be one of the principal causes of mechanical deterioration of cellulose insulation.

Water-Soluble Acids. Conditions that cause the formation of water-soluble acids also lead to the formation of water; and the combination of these acids and water leads to a corrosive condition. Corrosion occurs primarily on the tank area in the gas space and deposits of rust as thick as 1/16 to 1/8 inch often are found. Parts made of brass, lead, or cadmium seriously are attacked by such acids, the presence of which usually can be detected by the very rancid odor of the oil. The metal salts formed are in themselves objectionable in transformers.

Water-Insoluble Acids. High molecular weight or water-insoluble acids, while corrosive to some metals, are not seriously so, and it is questionable if they do any great harm as far as satisfactory operation of transformers is concerned. These acids do form metal soaps which are dispersed in the oil with a resulting increase in power factor. It is also true that these acids in themselves tend to increase the power factor of the oil and the contaminated oil in turn increases the power factor of the solid insulation that it impregnates. However, while high power factor of even as much as eight per cent may cause very slight losses in the dielectric itself, it is doubtful that any serious consequences will result. The tendency to develop localized heating as a result of high power factor is reduced because of the increased circulation of the oil. It is difficult to isolate increased power factor resulting from the presence of acids or other impurities that may not be harmful from an increase in power factor caused by the presence of water that, under certain conditions, might be very harmful.

Sludge Formation. With the continued oxidation of insulating oils, soluble oxidation products gradually are converted to insoluble products by polymerization or condensation which results in the formation of sludge. If sludging is allowed to progress to the point of clogging the cooling ducts, this shortly would result in a burnout. Often these solid products are metal soaps or a mixture of metal

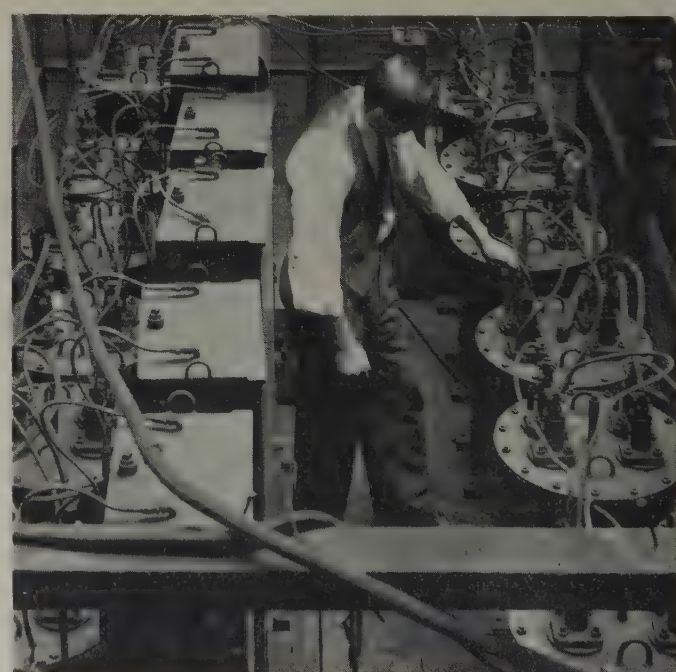

Figure 1. Much valuable information concerning transformer oil preservation has been obtained from this group of experimental transformers which has been operated for several years at the Westinghouse Electric Corporation equipped with different kinds of oil preservation equipment

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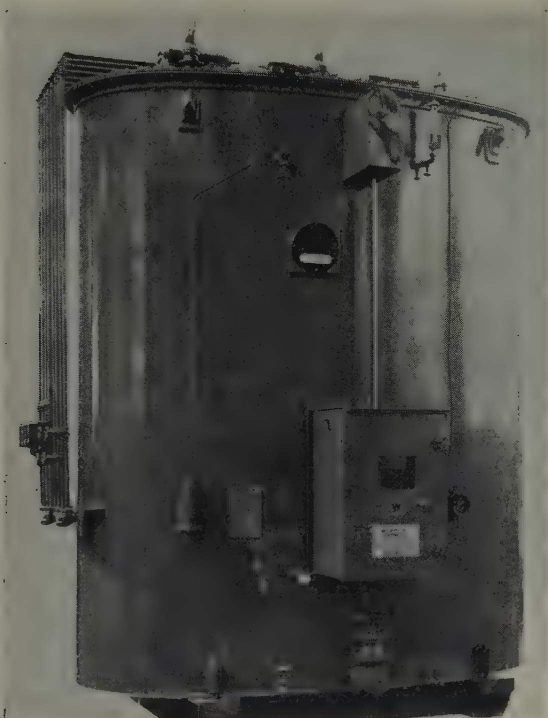
soaps and asphaltic residues. They are essentially nonconducting and not particularly harmful from the electrical standpoint.

The Westinghouse Electric Corporation has had on test for several years a group of small, experimental transformers equipped with various methods for oil preservation. Figure 1 shows a group of these transformers used in the experiment.

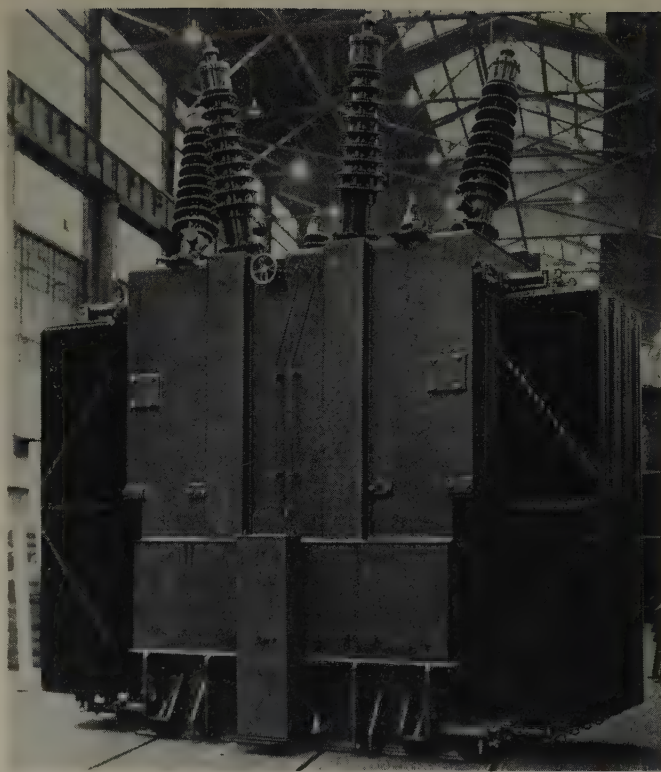
Complexity of Reactions. Oxidation with subsequent polymerization and condensation can take place simultaneously. If the oxygen is eliminated at any time during the oxidation cycle, the condensation and polymerization reactions still proceed and sludge and water may continue to be formed. Electrical breakdown when a transformer has been sealed completely and water continues to form usually is caused by either precipitation of the water from the oil onto critical surfaces from a supersaturated solution or possibly by localized condensation that drops into some critical area.

Rates of oil reactions can be accelerated materially by the different materials used in construction of transformers. Certain metals, particularly copper, are known to speed up the oxidation as much as five times. Small amounts of varnishes and gums in solution, as well as extractable material in the cellular insulation, can produce this effect. Proper selection and treatment of the materials reduces this effect. However, it is almost an impossibility to eliminate completely the accelerating effect of all of these materials. Deterioration of insulating oils in service can be reduced appreciably depending upon the type of apparatus and the control equipment used to protect it but the general character of the reactions cannot be changed to any great extent. Oxygen is perhaps responsible for the greatest amount of deterioration, but as far as the use of oil in transformers is concerned, water is undoubtedly the most objectionable impurity, whether it be present as moisture from in-breathed air or whether it is formed as a by-product of oxidation. Water causes more failures in electric apparatus, either directly or indirectly, than any other impurity.



Westinghouse photo

Figure 2. This free-breathing transformer is equipped with a dehydrator to protect against the entrance of moisture



Westinghouse photo

Figure 3A. In this Inertaire transformer, dry nitrogen is maintained over the oil to prevent oxidation

TRANSFORMER TANKS FOR OIL PRESERVATION

Free-Breathing Transformers. A free-breathing transformer is exposed both to the entrance of moisture and to the oxygen of the air. Methods of protecting the transformer against the entrance of moisture usually make use of dehydrating agents contained in some form of breathing tube. Figure 2 shows a free-breathing transformer equipped with a dehydrator. Agents such as calcium chloride can be used or active adsorbers such as silica gel or alumina are effective.

While oxidation of the oil takes place, the relative amount of harmful water-soluble acid does not increase excessively in a well-ventilated tank. These acids readily are expelled to the air. However, if volatile products are not carried off and remain to condense, definite reduction in the life of the oil as well as corrosion of metal above the oil level can be expected.

Restricted-Breathing Transformers. Breathing regulators when operated over a satisfactory pressure range reduce the rate of oil oxidation by maintaining a gas deficient in oxygen over the oil. The hot oil combines readily with oxygen breathed in liberating some carbon dioxide. Breathing can be reduced to a very limited degree by permitting outbreathing at about eight pounds above atmospheric pressure and in-breathing at about four pounds below atmospheric pressure.

Figure 3B. Equipment such as this keeps dry nitrogen constantly over the oil in the transformer of Figure 3a

Unless a breathing regulator is operated in series with a dehydrating unit, moisture can enter the transformer during in-breathing. Water also can be formed by oil oxidation within the transformer. If moisture is present in a transformer in the absence of oxygen, it will combine with the steel, forming rust and liberating hydrogen. The presence of hydrogen as determined by a gas analysis is almost a certain indication of water. This, of course, assumes that no arcing has taken place. This gives an indication as to whether a high power-factor oil is due to water or to other impurities.

Breathing regulators increase the life of the oil two or three times over that of a free-breathing transformer, if the tank remains tightly sealed and the transformer operates over a reasonable pressure range.

Inert Gas. For large transformers where the ratio of oil-to-air volume is high, an accepted practice is the use of an inert gas such as nitrogen automatically maintained by means of an accessory tank and reducing valve. A typical installation is shown in Figures 3*A* and 3*B*.

The use of nitrogen prevents oxidation of the oil even at maximum operating temperatures thereby markedly reducing the degree of deterioration of the cellulose insulation.

Hermetically-Sealed Transformer. Distribution transformers and some power transformers often are designed with hermetically-sealed bushings and welded-on covers as shown in Figure 4. This prevents oxidation of the oil and greatly extends the life of the transformer. In general the gas space initially is blown out with nitrogen. This is not absolutely necessary as the amount of oxygen originally present is small and when absorbed by the oil affects it to only a minor degree. It is most important that transformers of this type remain tight; otherwise, moisture may accumulate and oxidation take place with detrimental results. It is common practice on all sealed power transformers (501 kva and larger) to provide pressure and vacuum gauges. A comparison of the readings of these gauges between full load and no load conditions gives a positive indication of the tightness of the tank.

Expansion Tanks. As a protection against oxidation, expansion tanks as illustrated in Figure 5 are superior to open breathing. Oil in contact with air is at or is near ambient temperature and the rate of oxidation is quite slow. The oil in the expansion tank contains some oxygen in solution which eventually finds its way into the transformer and is consumed by reaction with the hot oil.

Westinghouse photo

Figure 4. Power transformer showing hermetically-sealed bushings and welded-on cover

Oxidation products thus formed are trapped in the transformer and will accumulate over a period of time. It is, therefore, possible to develop some water in the transformer that could give trouble. The life of oil perhaps can be doubled by the use of expansion-tank protection.

Oil Filter with Activated Material. Oil filters containing activated materials attached to the transformer so that the oil circulates through the filters by thermosiphon action are another means of preserving oil. These have been used to some extent and probably will be used even more in the future. The purifying material can be activated alumina, clay, silica gel, or carbon, but use of activated alumina and clay is the most common. Oil filters can be attached to new or old transformers as shown in Figure 6 and readily will absorb oxidation products, moisture, and other impurities and keep the oil in very good condition with respect to power factor, acidity, and dielec-

tric strength. The life of oil filters is to a large extent dependent upon the type and load cycle of the transformer to which they are attached. While the amount of active material required varies depending upon conditions, usually one to two per cent of the weight of the oil is sufficient. Periodic checks of the neutralization number of the oil will indicate when the usefulness of the active material has been exhausted. Under normal conditions it should not be necessary to replace or recharge the filter more than once a year.

Use of Inhibitors. Mineral oils usually contain natural inhibitors that reduce the rate of oxidation. Refining reduces the quantity of these inhibitors. Very good insulating oils can be made by refining to a high degree provided synthetic inhibitors are added to take the place of the natural inhibitors removed.

The use of inhibitors has been demonstrated well in lubricating oils but has been limited in transformer oils. Phenolic, amino, or sulphur compounds have worked well in laboratory tests or in trials in pilot transformers but are expendable and, once used up, behavior of the oil is very similar to that of uninhibited material.

The use of synthetic inhibitors commercially becomes difficult. Insulating oils from different sources may have been subject to different degrees of refinement. When combined in a common storage tank, life in transformers is unpredictable. Mixutre of these oils before or during service involves complications. Addition of inhibitors to partially oxidized oil is questionable in view of the many types of oil in service and the limited information available to date.

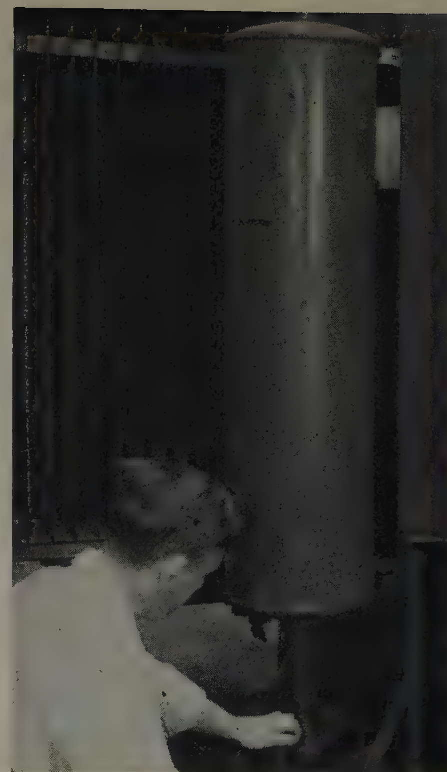
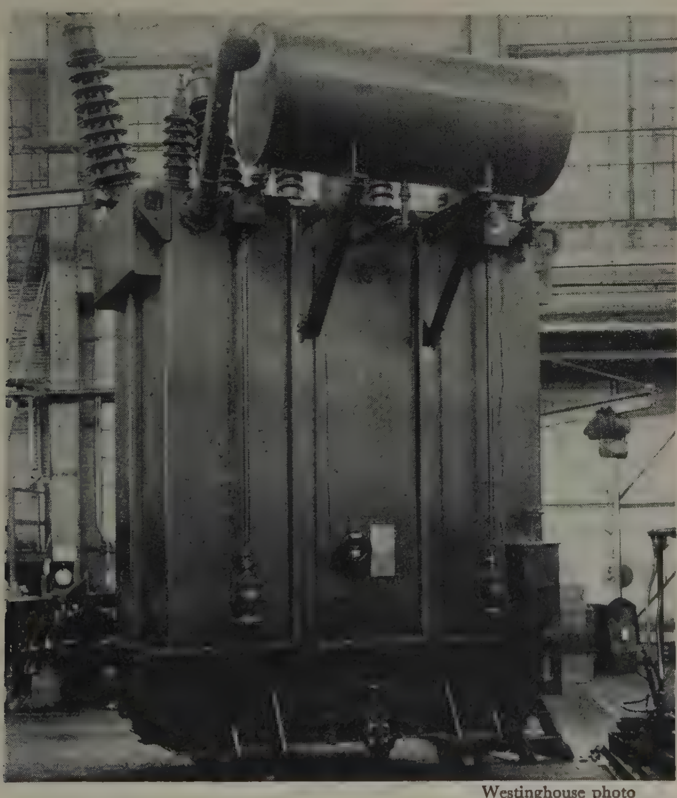


Figure 6. Oil circulating from the top to the bottom of this cylinder filled with absorbent material by thermosiphon action is cleaned of oxidation products, moisture, and other impurities

This is an early experimental installation



Westinghouse photo

Figure 5. Power transformers fitted with expansion tanks are superior to open breathing types

CONDITION OF OIL DURING OPERATION

At some time during the life of the average transformer, it usually becomes necessary to recondition the oil or replace it. Certain guides can be used to advantage assuming that periodic checks of the oil have been made at regular inspection intervals and that records have been kept of the test results.

Neutralization Number. A running curve on the neutralization number is of considerable value. When a sudden increase in the neutralization number is noted, accelerated deterioration is indicated. This should not be confused with minor changes, often negative, which come about as a result of sludge precipitation with varying temperature changes encountered in operation.

What maximum safe neutralization number can be permitted before reconditioning or replacing the oil is largely a matter of personal opinion. Some oils have been known to give trouble with reasonably low neutralization numbers and other oils to give satisfactory service with a neutralization number as high as 5. Other things, such as moisture, presence of corrosion, sediment and the like, must be considered. It generally is found when a neutralization number of 0.4 to 0.6 is attained that sludging begins. A value of 1.0 is a good point at which the oil should be reconditioned or replaced although this is not necessarily true for all oils in service.

Sediment Formation. Sediment formation is another guide that can be used to determine when the oil should be reconditioned or replaced. Sediment tests on a sample are not always positive indications of bad sludging. The only sure check is to remove the handhole cover or the main cover and make a visual inspection. A bad sludging condition often is indicated by a gradual temperature increase at a

given load and if allowed to continue it is likely that a burn-out will occur. When sludging has progressed to a degree where the cooling ducts in the windings have begun to clog, the only known method of removing the sludge is by mechanical means. This is not a simple process and deteriorated insulation can be damaged easily to the point of failure.

Corrosion. Corrosion in the gas space above the oil can be caused either by moisture or by a combination of moisture and acid oil. Progressive evaporation and condensation will cause a gradual accumulation of corrosion products which, if not removed, eventually will drop into the oil and may cause a failure of the transformer. Water-soluble metal salts may be carried to insulating surfaces and due to high conductivity cause creepage failures. This is sometimes the cause of high-voltage bushing failures. When evidence of corrosion is found, it should be corrected immediately and the oil put in good condition or replaced.

Interfacial Tension Test. A measure of interfacial tension recently has been proposed as a guide for judging the condition of oil in service. Various impurities will affect this value, such as acids, colloids, sediment, and so forth, and it is entirely possible that such a test, particularly when considered with other criteria, will be a valuable adjunct to the control of oil in the field.

RENOVATING TRANSFORMERS AND OIL

Treatment of Transformer. It is almost a practical impossibility to remove completely all impurities from transformers after sludging and corrosion have taken place. Perhaps the best general practice is to remove as much sediment as possible without damage to the insulation that may have lost much of its mechanical strength and to remove any corrosion products that may be present. The tank and core and coils then should be flushed with a reasonable amount of new oil.

Replacement or Recovery of Oil. Whether oil is replaced or recovered is primarily a question of economy based on laboratory tests and expert opinion. If reconditioning is decided upon, the method used depends to a large extent upon the condition of the oil.

Centrifuge or Filter Press. The centrifuge or the filter press, or a combination of the two, is undoubtedly the most common means of oil recovery. Both remove moisture and sediment thereby restoring good dielectric properties to the oil. These devices contribute little to the reduction of acidity or the prevention of further sludging and deterioration but they are valuable pieces of equipment as far as the general servicing of transformer oil is concerned.

Chemical Methods. Chemical methods sometimes are used to purify oil. Acids, esters, and other products of oxidation, can be removed either by alkali or mineral acids. Sodium hydroxide or sodium silicate as well as other alkalies will neutralize the acids and partly saponify the esters. A disadvantage is that the last traces of alkali soaps are removed only with difficulty and if allowed to remain in the oil greatly will accelerate deterioration when the oil again is placed in use. Strong acids, such as sulphuric or phosphoric, also will remove a large portion of the oxidation products, but the oil must be neutralized with an alkali to get rid of the last traces of acid. Here again, alkali soaps can be formed which may not be removed completely. Unless elaborate equipment is available equivalent to that found in a petroleum refinery, chemical recovery is not satisfactory.

Absorbing Agents. Another method of recovery that might be classed as chemical, or perhaps better, as physical, involves the use of absorbing or adsorbing agents such as activated clay, alumina, silica gel, or carbon. These materials, by selective absorption, will remove acids, colloids, moisture, and polar compounds quite effectively. The choice of a material and the method (whether contact or percolation) is a matter of opinion but, in general, activated clay or alumina and percolation are by far the most commonly used.

The relative amount of adsorbent to oil depends to a large degree on the extent of the oil deterioration. Generally, two or three per cent by weight will reduce the neutralization number from around 0.7 to below 0.1. At the same time the oil is dehydrated thoroughly and improved markedly in color. Removal of the impurities results in improved electrical properties, especially power factor and dielectric strength. These adsorbents must contain no free alkalies, otherwise, alkali soaps may be carried into the oil to give trouble later.

These adsorbing agents for oil recovery may remove desirable components such as natural or synthetic inhibitors as well as undesirable ones. This condition might be corrected by the addition of synthetic inhibitors but a knowledge of this subject is at present rather limited.

Not only can adsorbing agents be used for oil recovery, they can be useful in keeping oil in good condition while in service. As an example, a unit containing such material attached to a transformer will keep the oil in good condition over a reasonable period of time, depending on the relative ratios of the oil volume to the weight of material and the operating characteristics of the transformer. Periodic check of the oil properties will indicate when such a unit has been exhausted and when replacement is desirable. This mean of keeping oil in condition is being used increasingly and, in some respects, eliminates the desirability of adding inhibitors to the oil. It is probable that use of such units will be of great importance in the preservation of oil used in transformers in the future.

ASKARELS

Askarel is a generic name given to a class of liquids known to the trade as "fireproof dielectrics." Usually askarels are made by mixing together certain chlorinated compounds to obtain the correct physical characteristics for transformer application. To date, they have not been used in switchgear because hydrogen chloride is developed when askarel is arced and this gas, aside from being corrosive in the presence of moisture, has poor arc extinction properties.

Properties of Askarel. Askarel is considerably heavier than water. It is relatively nonoxidizing, but is a very strong solvent compared with oil. This means that the manufacturer must be extremely careful in the choice of insulating materials used in askarel transformers.

Table I. Summary of Methods for Preservation of Oil Based on Transformer Tank Design

	Inert Gas Provided by Nitrogen Cylinder	Sealed Tank	Sealed Tank Breathing Regulator	Expansion Tank	Open Breather
1. Inert gas above oil automatically maintained at positive pressure	Yes	No	No	No	No
2. Inert gas above oil automatically maintained	Yes	Yes	No	No	No
3. Air breathing prevented under normal operating conditions	Yes	Yes	Negligible	No	No
4. Entrance of moisture prevented	Yes	Yes	Negligible	Restricted	No
5. Gas cushion above oil	Yes	Yes	Yes	No	Yes
6. Main tank relief diaphragm	Yes	Yes	Yes	No	No
7. Protection of cellulose insulation	Yes	Yes	Partial	Partial	No
8. Relative rates of oil deterioration (estimated)	0.0 to 0.005	0.00 to 0.005	0.05 to 0.1	0.5	1.0
9. Negative pressure likely under normal operation	No	Yes	Yes	No	No
10. Positive indication of tightness of tank	Yes	Yes	Yes	Yes	No

Askarel has a dielectric constant approximately twice that of oil and quite comparable to that of solid insulation, thus a much better condition is obtained as far as the low-frequency breakdown strength of the combined insulations is concerned. The power factor of askarel is also usually higher than that of oil and, being polar, it is a fairly good ionizing medium. Thus, certain impurities will increase its power factor markedly although not affecting its breakdown strength substantially.

While the power factor of this dielectric is relatively high compared with oil this is no great disadvantage to its use in transformers, provided the liquid is not permitted to enter oil-impregnated insulation, such as used in cables or wound-type bushings where excessive heat cannot be dissipated. When dry, the low-frequency dielectric strength of askarel is generally 20 to 25 per cent above that of oil when tested in a standard test cup. Notwithstanding this fact, askarel sometimes behaves very peculiarly at high voltages and high frequencies and must be used with caution.

Although askarel is very sensitive to water like oil, in other ways it behaves quite differently because of its relatively high specific gravity. Free water in an oil-filled transformer usually separates and goes to the bottom of the tank where it is relatively cool. While the oil in contact with the water may be at the saturation value, it is saturated at a low temperature. As this saturated oil is drawn by thermal action through the core and coils, it quickly becomes undersaturated because of the increase in temperature. As a result, the oil does not carry any appreciable amount of free water to the coils and solid insulation. Because askarel has a high specific gravity, generally above 1.5, water tends to accumulate at the surface and to cause saturation where the temperature is the greatest. As the saturated liquid is carried by thermal action to the bottom of the transformer, it reaches a degree of supersaturation as it cools whereby a cloud may form. This cloud is free water that either will be absorbed by the solid insulation or attach itself to procelain, or other solid insulations, and reduce the creepage value.

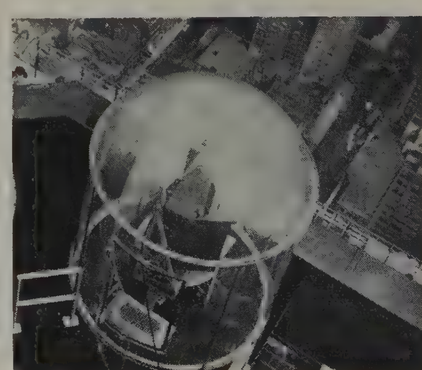
Care of Askarel. Impurities from solid insulation and moisture can be removed readily from askarel by filtration. While a filter press will remove moisture effectively, it will not remove soluble impurities that cause an increase in power factor. It is usually necessary to use an adsorbing agent, such as activated alumina or clay, to reduce power factor. These agents also will remove moisture very effectively and generally restore the dielectric strength. Oil is thoroughly miscible with askarel and cannot be removed effectively except by costly methods. Extreme care should be taken to isolate any source of oil, such as cables and potheads. The chief disadvantage of oil as an impurity is that it not only reduces the resistance of askarel to oxidation, but also it is a source of combustible gases in case of arcing. It is accepted generally that an amount of oil of less than five per cent is not particularly detrimental.

There is a very distinct difference between askarel and oil in case of transformer failure. Although the hydrogen chloride produced by askarel is not explosive and does not support combustion, it quickly will attack insulating materials and metal parts. In case of a failure, it is desirable to remove the hydrogen chloride from arced askarel as soon as possible by bubbling an inert gas, such as nitrogen, rapidly through the arced liquid. Recently, compounds have been found which, if added to askarel, will combine with hydrogen chloride and thus materially reduce its detrimental effects on insulation and lessen the possibility of corrosion of metal parts.

When this liquid has been arced badly, there is always a large amount of carbon formed which remains in suspension in the liquid for some time. This carbon can be removed by equipment very similar to that used for recovering transformer oil, particularly the filter press, although small amounts of hydrogen chloride and other impurities may remain and should be removed.

A better means of reconditioning is to circulate the arced liquid through activated clay or through activated clay and blotting paper until the carbon has been removed completely and until a satisfactory neutralization number and power factor are attained. The neutralization number of the recovered material should be less than 0.05 and the 60-cycle power factor not more than one per cent at normal temperature.

Plastics Protect Antennas



Television antennas of the New York Telephone Company atop the Empire State Building are protected from wind and weather by Plexiglas housings, 1/2 inch thick and 7 feet in diameter

True Dielectric Breakdown Strength of Cable Papers

PAUL CLOKE
FELLOW AIEE

BURT BATES

THE OBJECT of this study is to present a new unique way of controlling edge effect and thus obtain the true dielectric breakdown strength of electric cable insulating papers, to compare the dielectric strength of paper so determined with the dielectric strength of other materials and with the dielectric strength of built-up paper insulation, and to compare the dielectric strength of structures composed of saturated paper insulation with the intrinsic dielectric strength of the saturated paper.

This object is accomplished by a cell consisting of a specially shaped electrode and a system of insulating barrier build-up papers. The specimens are 5-mil paper and the barriers may be either of 1-mil or 1/2-mil rice paper or be prepared from specimen paper. Puncture thus is confined to the central 1-inch-diameter portion of special electrode.

Puncture is obtained by discharging a capacitor in the primary winding of a testing transformer. The cell in the secondary winding is paralleled by a voltage divider connected to an oscilloscope from the readings of which the breakdown voltage may be computed. The circuit is shown in Figure 1.

The bottom electrode of the cell is a highly polished flat circular disk. In Figure 2 the paper sample is *P* and the special electrode *S*. The latter was made in two sections, a flat central section of 1-inch diameter; the second section was machined according to the following derived curve (Figure 3).

The basic equation is

$$\frac{b}{t}=K$$

where

b = angle, in radians, between the tangent to the curved portion of the electrode and the horizontal

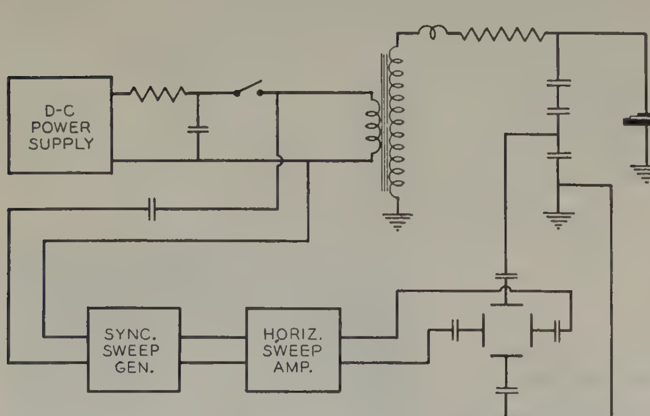


Figure 1. Electrical circuit diagram

Digest of paper 48-212, "The True Dielectric Breakdown Strength of Electric Cable Insulating Papers," recommended by the AIEE insulated conductor committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

Paul Cloke and **Burt Bates** are both with the college of technology, University of Maine, Orono, Maine.

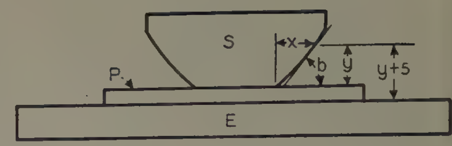


Figure 2. Special electrode (not to scale)

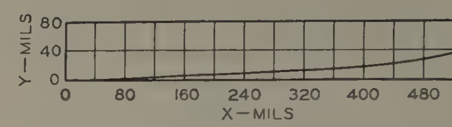


Figure 3. Plot of curved portion of electrode

t = thickness of insulation in mils

K = a constant

$$\frac{dy}{dx}=\tan b$$

$t=y+5$ (specimen is 5-mil paper)

when

$\text{Cot } b=50 \qquad b=0.02 \qquad y=0 \qquad K=0.004$

$$dx=\frac{dy}{\tan K\,(y+5)}=dy\cot K\,(y+5)$$

$$x=\frac{1}{K}\times\ln\sin K\,(y+5)+C$$

$C=978$

It was assumed that the strength in a transverse direction was of the order of 50 times that in a longitudinal direction. This insures transverse breakdown. Therefore cot $b=50$.

1. The special electrode made possible the determination of the true breakdown strength.

2. The build-up paper assembly is an essential component of the cell structure.

3. The average breakdown voltage is of the order of twice those previously reported.

4. The percentage of breakdowns occurring on the central flat portion of the special electrode were as follows:

Sample A, 55.9 per cent; B, 59.6 per cent; C, 60.7 per cent; D, 66.3 per cent, and E, 61.9 per cent.

5. The breakdown increases with increasing density of paper as shown in Table I.

Table I. Change of Breakdown Strength With Paper Density

Sample	Breakdown Volts Per Mil	Range of Breakdown Volts Per Mil	Specific Gravity
B	3,700	3,000 to 4,600	0.827
C	4,600	3,700 to 5,600	0.880
E	4,800	4,200 to 5,200	0.909
A	4,900	3,400 to 5,700	1.010
D	5,500	4,600 to 6,300	1.106

The authors are not aware of surge strengths in excess of 3,000 volts per mil being reported. Results are not in conflict with results obtained by other investigators.

Electrical Essay

4-Terminal Network

Geometrical Problem. Arrange six matches to form four equilateral triangles.

Answer. If the matches are set as the edges of a pyramid with vertices A, B, C, D, as in Figure 1, then each of the four equilateral triangular faces is bounded respectively by three of the four matches.

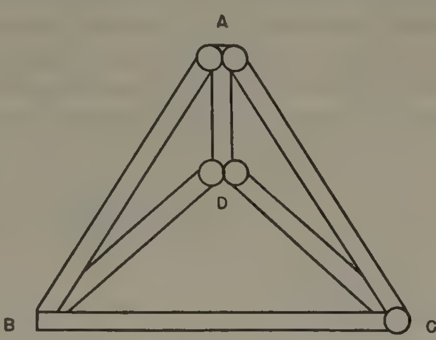


Figure 1

Electrical Problem. Given six transformers whose primaries may be energized respectively in any desired manner. Excite the primaries and connect the secondaries to four points, P, Q, R, S, in such a way that the voltages PQ, QR, RP, PS, QS, RS, as read by an a-c (rms) voltmeter are all the same.

Answer. See the December issue.

Answer to Previous Essay

The following is the author's answer to his previously published essay, "Electrical Heat Generation in Metal Bar" (*EE, Oct '48, p 978*). The answer is *false.*

The expectation that $(V_A-V_B)I$ and Q_{AB} are equal in magnitude is based in part on the following mathematical transformation.

We deal with steady-state conditions. Let V be the electric potential at any point. Let $E=-\text{grad } V$, a vector, be the electric field at any point. Let i, a vector, be the current density at any point. Take any closed geometric surface S. Then by Gauss' theorem

$$\iint V i_n dS = \iiint \text{div}(V\boldsymbol{i})d\tau$$
$$= \iiint (\boldsymbol{i}\cdot\text{grad } V + V \text{ div } \boldsymbol{i})d\tau$$
$$= \iiint \boldsymbol{i}\cdot\mathbf{E}d\tau, \qquad \text{since div } \boldsymbol{i}=0$$

If the closed surface S, consists of the sections A and B of the bar and the outer surface of the bar, then

$$\iint V i_n dS = (V_A - V_B)I$$

Thus we see that $(V_A-V_B)I$ is equal in magnitude to $\boldsymbol{i}\cdot\boldsymbol{E}$ integrated through the volume of the bar. This is all we can get from electrostatics, and the general laws of steady-state current flow.

If it were always true that $\boldsymbol{i}\cdot\boldsymbol{E}=q$, where q is the heat generated per unit volume, then of course, the stated proposition would be true. But in general, $\cdot\boldsymbol{E}\boldsymbol{i}$ is not equal to q.

For homogeneous metals, which are also isotropic in their properties, we have the following two *empirically* established laws: Ohm's law: $\mathbf{E}=\rho\boldsymbol{i}$; Joule's law: $q=\rho\boldsymbol{i}^2$; where ρ, a scalar, is a material constant, the electrical resistivity.

Hence for such homogeneous, isotropic metals, $\boldsymbol{i}\cdot\boldsymbol{E}$ is equal to q, and the stated proposition is true. However, for nonhomogeneous materials, neither Ohm's law nor Joule's law are generally true.

We may examine first an extreme case of nonhomogeneity namely, that of the contact of two dissimilar metals. For example, consider the junction where a copper bar is welded to a zinc bar. We find empirically, that even with zero current flowing along the composite bar, there is a potential drop across the junction, the so-called contact potential drop, U. For copper and zinc at ordinary temperatures, this contact drop amounts to several tenths of a volt, $U\cong 0.5$ volt. Furthermore, we find that if the junction temperature is kept constant, the potential drop across the junction is very little changed when current flows. Therefore, instead of Ohm's law we have for the junction

$$V_A - V_B = U_{AB}$$

where V_A and V_B are potentials respectively at point A just on one side of the junction, and point B just at the other side of the junction and U_{AB} is the contact potential of material A relative to material B.

We also find empirically that when current flows, there takes place at the junction a proportional evolution (or absorption) of heat, the factor of proportionality being W_{AB}, the Peltier coefficient. Thus, instead of Joule's law, we have for the junction $Q=W_{AB}I$

The Peltier coefficient for our zinc copper junction has a magnitude of a few tenths of a millivolt, $W_{AB}\cong 0.0005$ volt. Thus, W_{AB} and U_{AB} are widely different in magnitude. It follows then that $(V_A-V_B)I\neq Q_{AB})$ for the junction.

Returning now to the bar of our essay, let it be made of brass, but of varying composition along its length, so that it is 100 per cent copper at one end, and 100 per cent zinc at the other. Then for the spaced points A B instead of Ohm's law, we have $V_A-V_B=U_{AB}+R_{AB}I$ where U_{AB} is the contact potential difference we would find between two brasses of compositions A and B respectively, if we put them together.

Instead of Joule's law we have $Q_{AB}=W_{AB}I+R_{AB}I^2$ where W_{AB} is the Peltier coefficient for two brasses of composition A and B respectively. Hence, since U_{AB} and W_{AB} are not at all equal, $(V_A-V_B)I$ is not equal to Q_{AB}. Instead, we have $([V_A-V_B]+[W_{AB}-U_{AB}])I=Q_{AB}$ where

$$[W_{AB}-U_{AB}]\neq 0$$

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Editor's Note: See Doctor Slepian's letter to the editor on page 1130 for comments on previous essays.

Electrostatic D-C Transformer

JOSÉ MIRELES MALPICA
MEMBER AIEE

A SEARCH for a simple and inexpensive method of obtaining high voltages of direct current led to the conclusion that the magnetic transformer is a particular case of a more general type of phenomenon, namely, "electrical transformation," and that other types of electric transformers are possible. The principle of electrical transformation is stated in a tentative form as follows:

When electric energy transforms reversibly into another form of energy, electrical transformation is possible.

The following accessory statements also can be made:

1. Electrical transformation occurs when electric energy applied in a "circuit" can be taken from another "circuit" of the transformation system; both circuits may or may not be "conductively" independent.

2. The manner of application of the primary electric energy, the nature of the intermediate transformation energy and that of the medium in which it resides, and the manner of appearance in the secondary circuit determine the characteristics of the electric transformer.

3. The electrical transformation may occur immediately, or mediately, with a phase change, or a delay, according to the energy characteristics of the storage medium.

Taking this principle, and the accessory statements as a basis, it can be shown that any given type of electrical transformation can be represented symbolically by a simple diagram, from which the main properties of that particular type of transformer can be read. The principle of electrical transformation leads directly to new types of electric transformers, two of which are the "electrostatic transformer" and the "electronic transformer."

In the "electrostatic d-c transformer" the electric energy taken by the input or primary circuit is stored up in a moving dielectric in the form of "energy of the electric field" which in turn can appear as electric energy in the secondary circuit. The elementary theory for the air-immersed electrostatic transformer shows that for voltage gradients above breakdown of air, the initial transient current i is proportional to the primary voltage E_0, to the capacitance per unit area of the dielectric C_a, and to the rate of change of area per unit time dA/dt of the dielectric passing through the brushes. This value also applies to the secondary short-circuit current. The expression relating these factors together is

$$i = E_0 C_a (dA/dt)$$

The laboratory model consists of a glass disk moved by an electric motor. A pair of brass brushes with the dielectric between them, and placed radially, constitutes the "primary" terminals, which can be connected to a source of high voltage, either of direct current, or of alternating current. A similar pair of brushes, placed a short distance away, constitutes the "secondary" terminals (see Figure 1).

Several sets of primary and secondary terminals can be placed around the axis of rotation. Because the polarity of the secondaries is determined by the polarity of the primaries, it is possible to connect the primaries in parallel and the secondaries in series, or vice versa, constituting in this way a step-up or step-down d-c or a-c transformer. If alternating current is used, the dielectric must move synchronously, to avoid residual polarizations out of phase with the applied voltage. For extremely high voltages sets of disks placed on the same shaft can be arranged with the series connection along a sectional cylinder parallel to the axis of rotation.

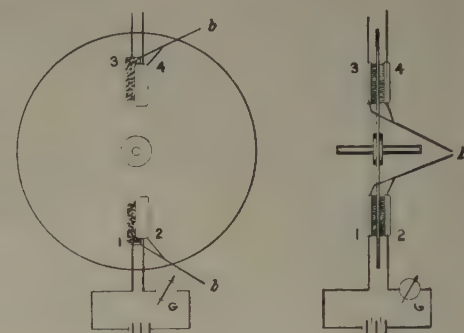

Figure 1. Diagram of the electrostatic transformer with terminals 1 and 2 serving as the primary, and terminals 3 and 4 as the secondary

In the air-immersed electrostatic transformer, the "contact" between the brushes and the surface of the disk occurs mainly through the cushion of ionized air, giving a nonlinear current–voltage characteristic, except for voltage gradients at the disk above the breakdown of air.

The voltage output can be varied by changing the primary voltage, and the maximum secondary current can be controlled by the speed of the disk. This flexibility makes the device extremely useful in the laboratory as a source of high direct voltages. By use of the new high-dielectric-constant ceramics,[1] the power rating of the apparatus can be increased greatly, presenting the possibility of industrial applications.

An example of the adaptability of the electrostatic d-c transformer to extremely high voltages is the possibility of using it to step down to useful values the potentials that can be obtained from the disintegrations of some radioactive substances.[2]

REFERENCES

1. High Titania Dielectrics, **Eugene Wainer.** *Transactions*, Electrochemical Society (New York, N.Y.), volume 89, 1946, pages 47–70.

2. Electrostatic Sources of Electric Power, **John G. Trump.** *ELECTRICAL ENGINEERING*, volume 66, June 1948, pages 525–34.

Digest of paper **48-155**, "The Electrostatic Transformer and Its Possible Application to the Direct Utilization of Nuclear Energy," recommended by the AIEE nucleonics committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Principles of Protective Relaying

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Development of relaying to improve fault isolation in power systems has led to many devices and schemes. The more commonly used relay characteristics and their underlying principles of operation are summarized in this article for convenient reference and comparison.

THE rapid growth in power system size and interconnection over the past 30 years has increased greatly the problem of isolating faults surely and quickly. Standards of service have increased thus making necessary greater reliability and higher speed of operation. Innumerable relaying devices and schemes have been developed to meet these ever-more-exacting requirements. Some have been designed for special situations; others apply to basic situations which occur on many systems. It is these latter which are discussed here.

The AIEE through its relay committee has greatly encouraged these developments through the dissemination of information in hundreds of technical papers, conferences, and committee reports. The committee maintains an up-to-date bibliography of these papers and reports, as well as of other published articles and books.

GENERAL PHILOSOPHY OF RELAYING

The system is divided into protective zones as shown in Figure 1, each having its protective relays for determining the existence of a fault in that zone and having circuit breakers for disconnecting that zone from the system. It is desirable to restrict the amount of system disconnected by a given fault, as, for example, to a single transformer, line section, machine, or bus section. However, economic considerations frequently limit the number of circuit breakers to those required for normal operation and some compromises result in the relay protection.

The relays operate usually from currents and voltages derived from current and potential transformers or potential devices. A station battery usually provides the circuit breaker trip current. Successful clearing depends on the condition of the battery, the continuity of the wiring and trip coil, and the proper mechanical and electrical operation of the circuit breaker as well as the closing of the relay trip contacts.

In event of failure of one of these elements, so that the fault in a given zone is not cleared by the "first line of defense"—relays and circuit breakers—some form of back-up protection ordinarily is provided to do the next best thing. This usually means first of all to clear the fault automatically, if at all possible, even though this requires disconnection of a considerable portion of the system. Once cleared, the system generally can be restored rather quickly, whereas if the fault "hangs on," the line may be burned down or apparatus damaged beyond repair, or the entire system may be shut down for an extended period. The measures taken to provide back-up protection vary widely depending on the value and importance of the installation and the consequence of failure.

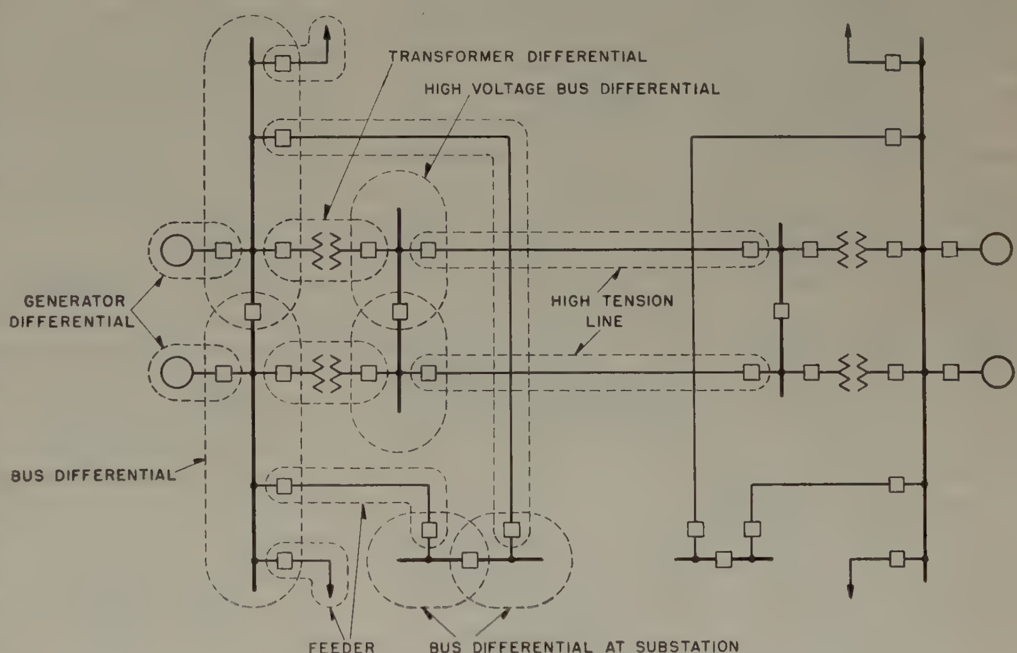


Figure 1. Typical system showing protective zone

Some utilities in measuring the performance of transmission line relay protection analyze all relay trip operations as shown in Table I. The figures shown are typical of a system operating 3,000 miles of 110-kv line. This is only an analysis of faults for which the relay tripped or should have tripped. For each of these there were several cases where the relays should not have tripped, and did

Essential substance of paper 48-186, "Principles and Practices of Protective Relaying in the United States of America," presented at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

E. L. Harder is consulting transmission engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., and **W. E. Marter** is relay engineer, Duquesne Light Company, Pittsburgh, Pa.

not. Thus the total number of discriminations made by the relays is possibly 5 to 10 times as great as the trippings. The percentage failures are correspondingly less on this larger basis.

However, the table is presented at this point to bring out

Table I. Relay Operations by Percentages

Correct and desired	92.2
Correct but undesired	5.3
Wrong tripping operations	2.1
Failure to trip	0.4

the factors that enter into a highly successful protective relay system. These are

1. Good equipment, relays, instrument transformers, and the like.
2. A system design that can be protected and correct application of relays to provide the possible protection.
3. Good maintenance primarily to assure that all the accessories are operative.

The "correct but undesired" trippings are cases where the relays have done what should be expected from their characteristic curves and settings and the fault conditions involved. There may have been system changes since their application, or incorrect initial application, or application with foreknowledge that certain conditions unavoidably would operate the relays, but this was necessary to secure tripping in other desired cases.

It is important to bear in mind that simple standard system design plans can be better protected. Also, distance measuring and carrier or pilot wire types of relaying are much less subject to disqualification by system changes than are overcurrent types.

Wrong tripping and tripping failures together with all causes of failure to clear faults have been broken down further in AIEE conference reports and found to stem largely from human errors, such as leaving the trip circuit open after test, or to open-circuited trip coils, or mechanical failure of the circuit breaker, and blown fuses in trip circuits (if used). Only a small part of the total failures occur in the protective relay itself. Thus close attention to the initial design, installation, testing, and maintenance of all of the accessory equipment as well as of the protective relay proper are needed to assure successful operation.

The application of protective relays properly requires evaluation of several factors, namely,

1. The requirements of the power service and desired functioning of the system during fault conditions to produce this result.
2. The currents, voltages, temperatures, pressures, or other indicators at time of fault which provide the fundamental basis of discrimination.
3. The characteristics of available or standard relay elements.
4. The "schemes" in which they are used.

A wide variety of characteristics are now available operating in response to the prime quantities themselves, as listed in item 2, or to various functions of these prime quantities, such as power, phase angle, power factor, current comparison, power comparison, impedance, reactance, modified reactance, current ratio, or phase-sequence component. In each case the response may be "instantaneous," meaning an intentional delay, or the operation may depend in a predetermined manner on the electrical quantities and time of duration.

BASIC ELEMENTS

By taking some liberties with exactness and making no pretense of completeness, the more commonly used relay characteristics and their underlying principles of operation may be listed here. The schemes in which the elements are used are, of course, much more numerous. Principles of a number of the more commonly used relay elements are shown in Figure 2.

Instantaneous Elements. For instantaneous response to current or voltage the solenoid element (*a*) is most common, appearing individually or as the "instantaneous attachment" with the induction-type overcurrent relay. The beam element (*b*) with spring or weight bias is used where low burden is desirable, as when setting for low ground currents with low-ratio bushing current transformers. The polar element (*j*) is of far lower burden than the nonpolar types and has come into widespread use since 1935 as the receiver relay of directional-comparison carrier equipments, and the basic element when supplied from networks or electronic devices. For example, it appears as the operating element in a pilot wire relay, in a phase-comparison carrier relay, in linear-coupler bus protection, and in supervision of pilot wires.

Because of its higher pick-up to drop-out ratio and less accurate setting the clapper type element (*c*) is used less frequently for the primary protective functions, but is used widely as an auxiliary relay.

Induction Elements. The induction-disk element (*d*) continues to be most widely used, its reliability and inherent time characteristic giving it great flexibility for co-ordinating relays in series or co-ordinating with fuses or direct-trip devices. A variety of characteristics are available from the definite-minimum-time, which is ideal for securing definite time steps between relays, to the very inverse which provides faster tripping with the same margins when the fault current drops considerably from one relay location to the next. The more inverse characteristic also co-ordinates better with fuses.

The induction disk also serves as a directional element (*e*) or, when used with a spring, as a watt element (*l*) the electric torque being proportional to $EI \cos \theta$, where θ is the power-factor angle. Either of these, of course, can be current polarized instead of voltage polarized for use in ground relaying when a bank-neutral current is available.

The relative phase of voltage and current can be shifted by internal or external phase-shifting devices to produce maximum torque for power factors other than unity, as in (*g*). For example, the directional element for ground relaying usually has its maximum torque for current lagging the voltage by 60 or 70 degrees to provide maximum torques for the fault conditions. A pure watt characteristic is used with the 30- and 60-degree connections for phase directional relays, the phase being provided by using the voltage of a different phase from the current. With the 90-degree connection this shift is too much and the voltage is advanced about 45 degrees by a phase shifter

Figure 2. Basic principles of commonly used relay elements

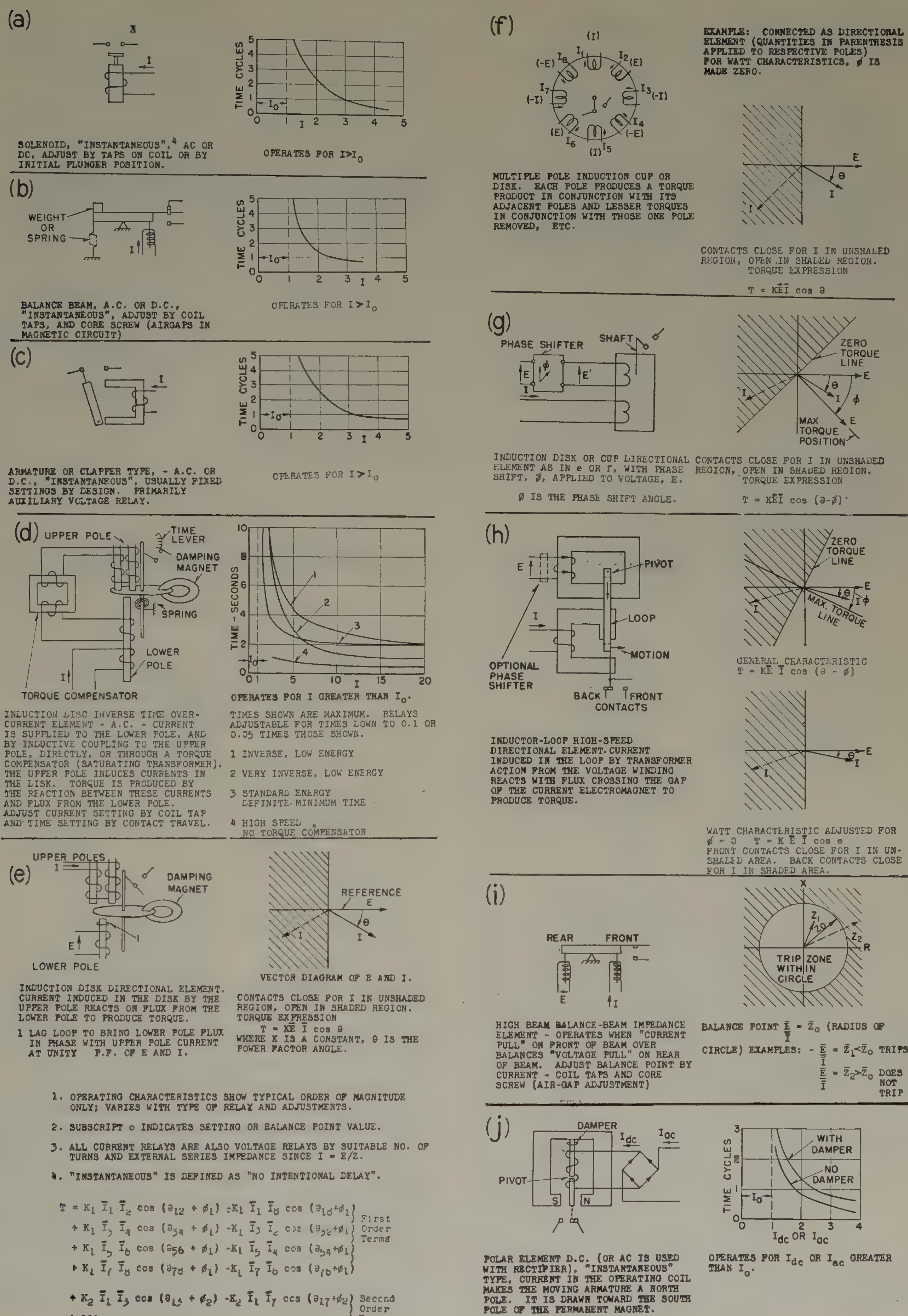
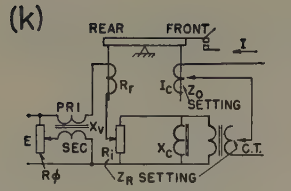
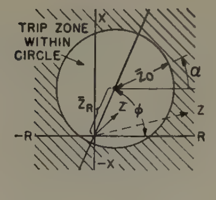


Figure 2 (continued). Basic principles of commonly used relay elements

(k)





HIGH SPEED BALANCE BEAM MODIFIED IMPEDANCE ELEMENT. ADJUST IMPEDANCE RADIUS OF CIRCLE, Z_0, BY CURRENT COIL TAPS, E, AND CORE SCREW (AIR GAP). ADJUST ANGLE OF LINE ALONG WHICH CENTER IS SHIFTED BY TAPS ON RESISTOR, R_ϕ. ADJUST IMPEDANCE Z_R BY WHICH CENTER IS SHIFTED BY TAPS ON CURRENT TRANSFORMER, C T., AND ON RESISTOR R_1.

DISPLACED CIRCLE IMPEDANCE CHARACTERISTIC.

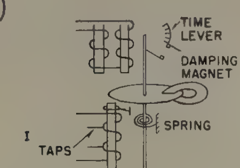
RELAY TRIPS FOR ALL FAULTS FOR WHICH IMPEDANCE, Z, SEEN BY RELAY FALLS WITHIN CIRCLE.

$\bar Z_0$, $\bar Z_R$, AND ϕ ARE ADJUSTABLE

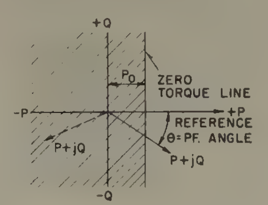
BALANCE POINT LOCUS:-

$Z = \bar Z_R e^{j\phi} + \bar Z_0 e^{j\alpha}$ FOR ALL VALUES OF α

(l)



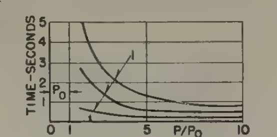
TYPICAL POWER VECTOR DIAGRAM



INDUCTION TYPE POWER RELAY. OPERATING TORQUE IS PRODUCT OF CURRENT INDUCED IN DISK BY UPPER POLE AND FLUX FROM LOWER POLE.

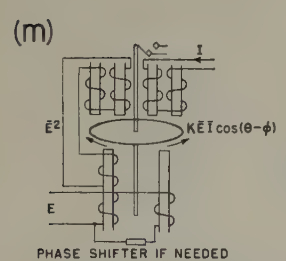
1. LAG LOOP TO BRING LOWER POLE FLUX IN PHASE WITH UPPER POLE CURRENT AT UNITY PF OF E AND I.

$P + jQ = \bar E\ I$ ($P = \bar E \bar I \cos\theta$) CONTACTS CLOSE FOR P + jQ IN UNSHADED REGION WITH TIMING AS INDICATED BELOW.

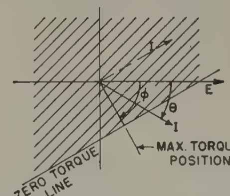


1. ON TYPICAL TIME LEVER SETTINGS

(m)



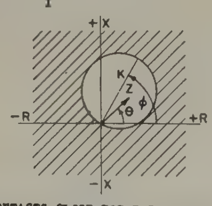
INDUCTION IMPEDANCE ELEMENT $\bar E^2$ PULLING AGAINST $K\bar E\bar I\cos(\theta-\phi)$



CURRENT TRIPPING CHARACTERISTICS WITH FIXED VOLTAGE. CONTACTS CLOSE FOR I IN UNSHADED AREA. BALANCE POINT AT

$$\bar I = \frac{\bar E}{K\cos(\theta-\phi)}$$

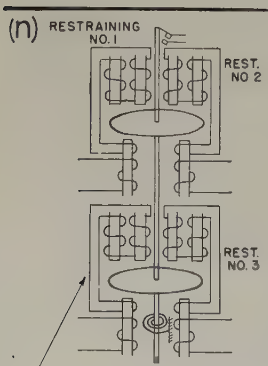
or $\bar Z = \frac{\bar E}{\bar I} = K\cos(\theta-\phi)$

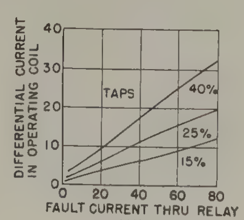


CONTACTS CLOSE FOR Z IN UNSHADED AREA. BALANCE POINT AT

$$\bar Z = \frac{\bar E}{\bar I} = K\cos(\theta-\phi)$$

(n)

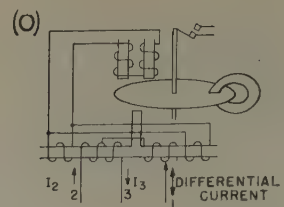


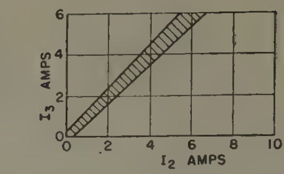


CONTACTS CLOSE FOR CURRENTS ABOVE CURVE CORRESPONDING TO RELAY SETTING.

(LEFT) THREE WINDING TRANSFORMER DIFFERENTIAL RELAY. (DAMPING MAGNET NOT SHOWN) ADJUST BY TAPS ON OPERATING WINDING. (ALSO SEE FIGURE 8a)

(o)

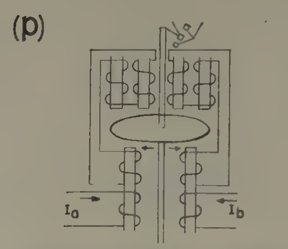


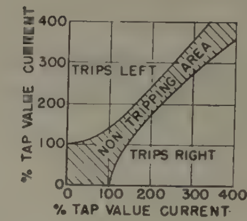


INDUCTION-TYPE RATIO-DIFFERENTIAL RELAY FOR GENERATOR AND TRANSFORMER PROTECTION.

OPERATES IN .1 TO .2 SEC. ON HEAVY FAULTS. CONTACTS CLOSE FOR CURRENTS IN UNSHADED AREAS. (I_2 and I_3 APPROX. IN PHASE) SCALE SHOWN IS FOR A 10%-DIFFERENTIAL GENERATOR RELAY.

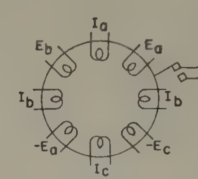
(p)

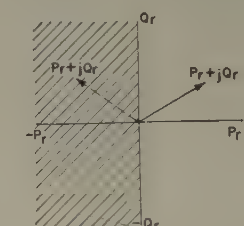




INDUCTION TYPE PHASE BALANCE RELAY (CONTACT NORMALLY SPRING CENTERED) (A SECOND DISK ON SAME SHAFT BALANCES I_a VS I_c)

(q)

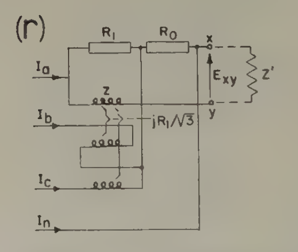




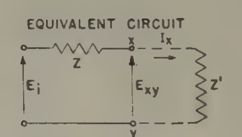
6 POLE INDUCTION CUP OR DISK CONNECTED AS A POLYPHASE DIRECTIONAL ELEMENT.

RESPONSE PROPORTIONAL TO $P_R+jQ_R = K(\bar E_1\bar I_1\cos(\theta_1-60+\phi) + \bar E_2\bar I_2\cos(\theta_2+60+\phi))$ CONTACTS CLOSE FOR P_R+jQ_R IN UNSHADED REGION. θ_1 AND θ_2 ARE POSITIVE AND NEGATIVE SEQUENCE PF ANGLES; ϕ IS RELAY DESIGN OR ADJUSTMENT ANGLE.

(r)



EQUIVALENT CIRCUIT



COMBINED POS.-SEQ. CURRENT AND WEIGHTED ZERO SEQ. CURRENT FILTER

$I_x = \frac{2R_1}{Z+Z'}(I_1 + K I_0)$

where

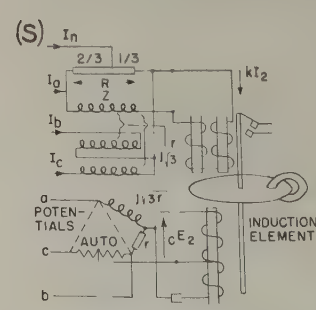
$K = \frac{3R_0 + R_1}{2R_1}$

THE INTERNAL VOLTAGE IS:- $E_i = 2R_1(I_1 + K I_0)$

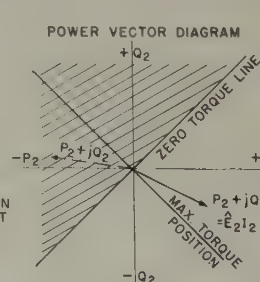
THE INTERNAL IMPEDANCE IS:- $Z = R_1 + R_0 + z$

WHERE z IS THE IMPEDANCE OF INDICATED WDG. OF 3-WDG. REACTOR

(s)



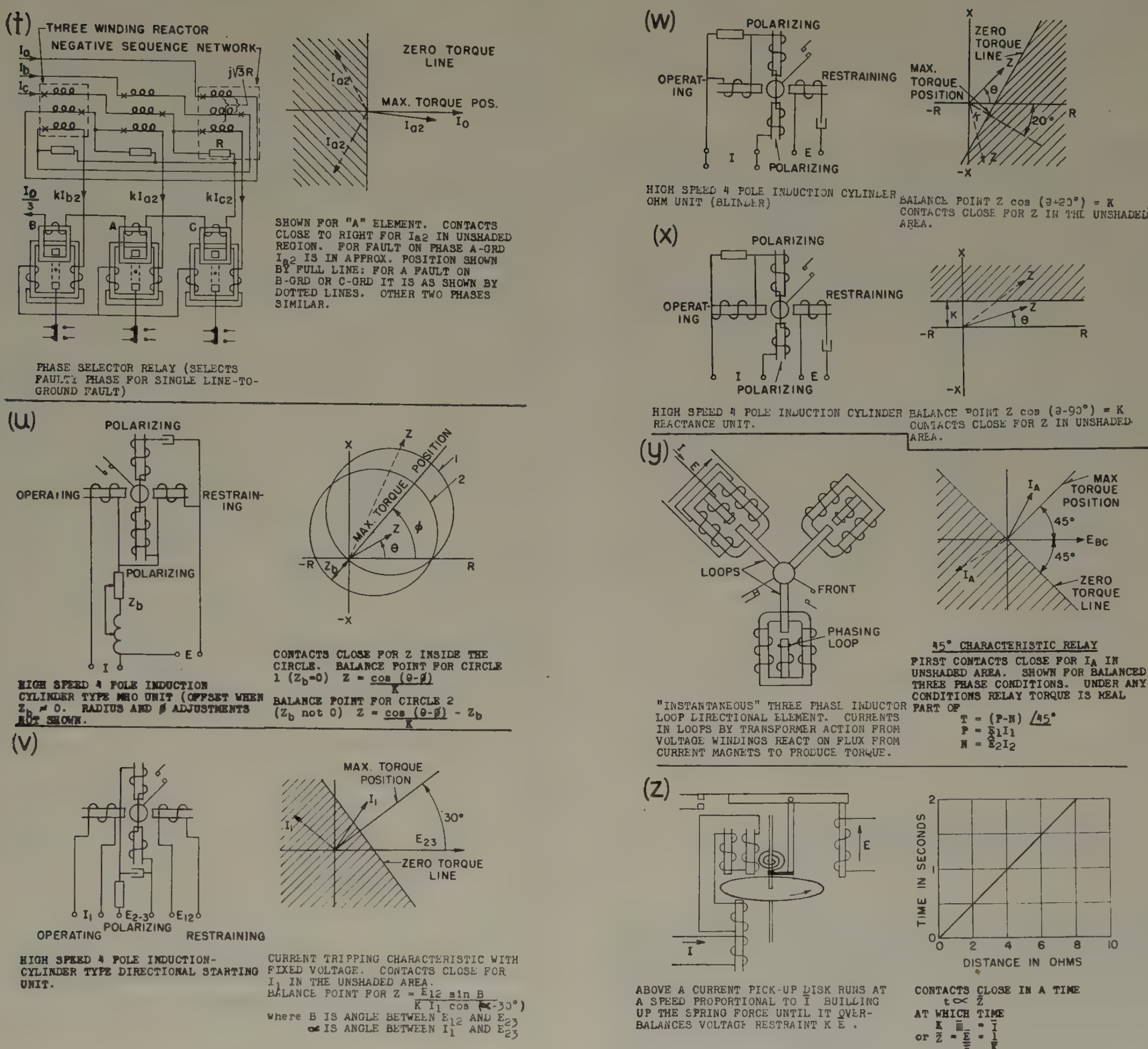
POWER VECTOR DIAGRAM



NEGATIVE SEQUENCE DIRECTIONAL ELEMENT - USING POTENTIAL, E_2, AND CURRENT, I_2, SEQUENCE SEGREGATING NETWORKS.

CONTACTS CLOSE FOR P_2+jQ_2 IN UNSHADED REGION.

Figure 2 (concluded). Basic principles of commonly used relay elements



to provide a maximum-torque position for a current 45 degree lagging.

The disk also is provided with a special electromagnet (*o*) producing ratio characteristics for use as a differential relay for generators or transformers. The generator-differential relay is illustrated, the transformer relay having windings 1 and 2 tapped also for different current-transformer ratios. With reference to Figure 2*o* the differential current produces lower-pole flux which acts in the operating direction on disk currents produced by the upper pole which is transformer fed from the same differential current. The restraint torque giving the ratio-differential characteristic is produced by the through current in coils 2–3, which supply disk current by transformer feed to the upper pole, and by lower-pole flux produced by the same through current.

The induction disk also provides a tripping-time-proportional-to-impedance characteristic as shown in Figure 2*z*.

Multiple Electromagnets or Disks. Two electromagnets on the disk provide for balancing mechanical torques with no phase angle effects [see (*p*)]. When these are both current electromagnets, the relay is the regulating transformer differential relay which balances the current in the shunt exciting winding against the through line current. For example in a ±10 per cent regulating transformer, it operates when the shunt current exceeds about 15 per cent of the through current.

When both electromagnets are voltage energized the voltage-differential relay results. When one is voltage (actually responsive to KE^2) and one is a product element, $EI \cos(\theta - \phi)$, a balance occurs when $I \cos(\theta - \phi) = KE$. This impedance characteristic is shown in current and also in an R–X plot in (*m*).

A second disk on the same shaft provides space for two more electromagnets. This structure is used as the phase-balance relay for motor protection, whose charac-

teristics are shown in (p). It also is used for the 3-winding-transformer differential relay, using one operating electromagnet and three restraint electromagnets (n).

With two current-input windings on each electromagnet and two relays per phase, the multirestraint bus differential relay results.

Multiple-Pole Cylinder or Disk Elements. The multiple-pole cylinder or disk element is illustrated in (f). The example shows how it would be energized to act as a single-phase directional element having torque proportional to $EI \cos \theta$. This element also serves as a polyphase-directional element by the connection (q). The multiple-pole element is very flexible, making possible a wide variety of other combinations.

Four-Pole Induction-Cylinder Elements. These high-speed elements serve a variety of purposes illustrated in (u), (v), (w), and (x). The element u, designated a mho element, operates with torque $EI \cos (\theta - \phi)$ restrained by torque proportional to E^2. It produces the circular-impedance-tripping locus passing through the origin or relay location. The circle may be shifted from this position by current compensation IZ_b in the restraining circuit, as indicated.

A directional-starting unit (v) is obtained using current times shifted-quadrature voltage for operating and the product of two delta voltages for restraint. This results in maximum torque for current 30 degrees ahead of the quadrature voltage or about 60 degrees lagging the unity-power-factor position.

The special impedance characteristic (w) obtained by I^2 operating against $EI \cos (\theta + 20 \text{ degrees})$ is used to restrict the tripping area to assist other relays in differentiating heavy load swings from faults. A reactance element (x) is obtained similarly with the phase-shift devices arranged so that the maximum-torque line is along the x (reactance) axis.

Inductor-Loop Element. The inductor loop (h) provides a very high speed and very reliable directional element which has been used for many years now in high-speed distance measuring relays.

Balance-Beam Element. The basic balance-beam impedance element is shown in (i), a balance occurring for $E/I = Z_0$. For higher impedances than Z_0 (current relatively lower) the contacts remain open whereas for lower impedances (relatively higher currents) they close quickly. Since the balance is mechanical, the phase angle between voltage and current is of minor consequence and the tripping characteristic, plotted on an R and X diagram, is substantially a circle.

Modified-Impedance Characteristic. The circular characteristic may be shifted by some circuits auxiliary to the element as shown in (k), in order to provide better discrimination between fault currents and load and swing currents on long, heavily loaded transmission lines. The shifting imparts a directional characteristic to the relay in addition to narrowing its tripping region to more nearly just that required for faults.

Networks and Auxiliary Circuits. It may be noted that in discussing fundamental relay elements certain auxiliary circuits, external to the mechanical relay have been introduced; in (g), the phase shifter; in (j), the rectifier; and in (k), a full fledged network to produce the desired currents in the relay element proper. This is a trend of which more will be seen as time goes on, as static circuits are devised to produce a simple current output proportional to the desired function of the various line currents and voltages.

Sequence-Segregating Networks, $I_1 + KI_0$. The method of symmetrical components has been the key that has unlocked the door to a number of the aforementioned possibilities, some of which are illustrated in (r), (s), and (t). The positive- and zero-sequence network in (r) commonly is used in pilot-wire relaying, where it is desired to compare over the wires only one quantity, which is a good measure of the fault current irrespective of what kind of fault it may be, that is, $A-B$, A-ground, or ABC. The relay can be given almost independent and widely different settings for phase faults and ground faults, using the single relay element. For example, it may be set for one ampere of ground fault to provide the requisite sensitivity, but for 10 amperes of 3-phase current to avoid operation on loads.

A negative-sequence directional element is illustrated in (s). It is an adequate directional element for ground faults on reasonably well grounded systems, and requires only two potential transformers rather than three as with usual residual-directional relays.

Another novel application (t) is the phase-selector relay to determine which phase is faulted. This information is necessary in single-pole tripping and reclosing schemes. It is predicted on the knowledge, from symmetrical-components theory, that the negative-sequence current in the faulted phase only is in phase with the zero-sequence current. Individual overcurrent elements in the three phases could not be used for this selection as all three would pick up for a single line-to-ground fault on many solidly grounded systems.

SOME APPLICATIONS OF RELAYS

Brief mention will be made of certain subjects and special relay problems in order to indicate some of the applications of protective relaying.

Industrial Interconnections. When a line is tapped to an industrial plant having generation, it is common practice to segregate essential loads for operation from the plant generator and dump others in event of a line outage. If the same line is tapped for other plants, the problem arises of separating the plant under consideration from the line under conditions hazardous to its operation. One scheme in successful use on many industrial interconnections consists of separation based on any of three indications provided power flow has reversed and is toward the power company. The three indications are: under frequency, undervoltage, or generator overload. Any of these occurrences, provided power flow is away from the plant, is taken as sufficient cause for separating and at the same time dumping nonessential loads so that the remaining plant

load may be brought within the capacity of the plant generation.

The relays normally employed are

1. Induction-type overcurrent for generator overload.
2. Induction-type under-frequency relay.
3. Induction-type undervoltage relay.
4. High-speed-type 3-phase directional relay.

The generator overload relay is directional controlled so that it will not start timing unless direction in the interconnection has reversed.

Directional relays also are used, without the voltage, frequency, or current fault detectors, for this purpose.

3-Terminal Lines. Lines having three or more terminals are generally more difficult to protect than 2-terminal lines. A-c pilot wire protection is applicable in many cases although the limiting values of pilot-wire capacitance and resistance are less per terminal than for 2-terminal lines. Carrier schemes, particularly of the blocking type, are applicable to multiterminal lines. However, sequential operation of circuit breakers occurs if fault current of appreciable magnitude flows out at one terminal for an internal fault near another terminal. The first-zone impedance element nearest the fault, acting independent of carrier current, opens the first circuit breaker, after which carrier current is stopped by the directional elements permitting clearing of the other circuit breakers.

Out-of-Step Protection. Practically all utilities, except those consisting of steam stations connected rigidly together electrically, have experienced system instability. Most utilities have experienced some undesired operation of fault-protective relays as a result of system instability. Quite a number of utilities attempt either to block line relays from tripping because of out-of-step conditions, or to set the relays so that tripping will occur at a preselected point. Out-of-step blocking in conjunction with carrier relaying is the method most commonly employed.

Synchronous frequency changers interconnecting two systems may suffer mechanical damage to shafts and couplings if permitted to operate with the systems out-of-step. The resulting power pulsations may be close to the natural frequency of the 2-mass system composed of the two rotors with connecting shaft. Out-of-step relays are available which detect a slip cycle by the power reversal at high current and can be set to trip after two or three slip cycles, or before serious torque oscillations can build up.

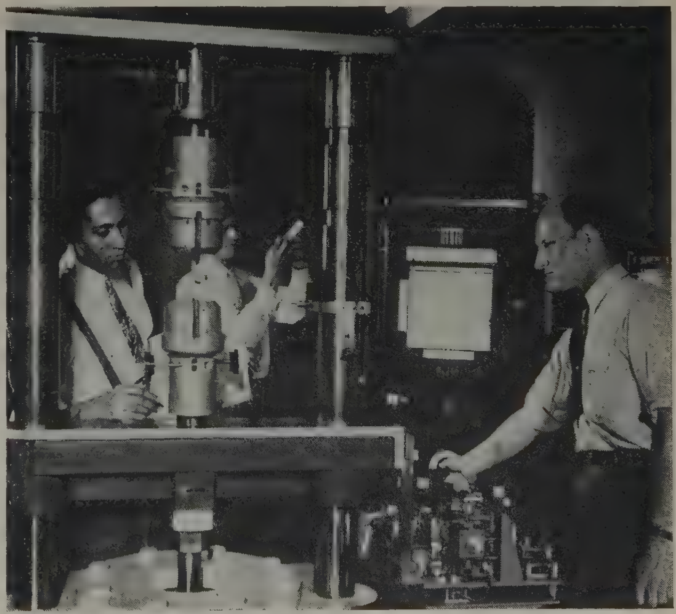
Quick Clearing of Faults. Modern 8-, 5-, and 3-cycle circuit breakers and high-speed relays are well accepted as a measure of prime importance in improving system stability and reducing damage and permanent outages. Case after case could be cited where these improvements have been realized as circuit breakers and relays have been modernized up to present-day standards.

High Speed Reclosing. Simultaneous operation of circuit breakers at the two ends of a transmission line by carrier-current or pilot-wire relaying has made possible high-speed reclosing. This measure is generally accepted as economically of greatest benefit in improving stability and service reliability. Three-pole reclosing has been most widely used. However, there are a number of applications of single pole reclosing which further enhances the stability by leaving the sound phases in service while the faulted ones are opened and reclosed.

TESTING AND MAINTENANCE

Routine tests are made by many companies at quite frequent intervals such as 1 to 3 months, depending on the importance of the service. However, the major calibration tests generally are scheduled for periods more of the order of six months to two years. One year is a quite common period. There is a decided feeling that too frequent testing may cause more harm from mistakes and inadvertent damage than the good that is accomplished. The tests vary from the over-all or primary test in which current is passed through the primary winding of the current transformer, and the circuit breaker tripped by the resulting relay action, to much less complete checks. A quite usual procedure would be to remove the relays from service and test and calibrate on a load box, and to check the instrument transformers for continuity and grounds. The instrument transformer–relay circuit is grounded at only one point so that the intentional ground can be lifted for this test. If feasible the circuit breaker may be tripped by closing the relay contact.

Plastics Testing Machine



This scene, from a recently released color motion picture describing a research project in plastics, shows a plastics testing machine that is controlled automatically by a servomechanism and includes an instantaneous recorder making possible tests involving temperature, torsion, bending, and constant rates of load and movement. The project was sponsored by the Plastic Material Manufacturing Association and was conducted in the Massachusetts Institute of Technology laboratories

An Automatic Standing Wave Indicator

PHILIP J. ALLEN

STANDING WAVE PATTERNS in an *X*-band wave guide are reproduced on a cathode ray tube in a new automatic standing wave indicator developed at the Naval Research Laboratory. The essential units of the instrument are a novel motor-driven "reciprocating probe," conventional high-gain audio amplifier, and a special cathode ray indicator. The reciprocating probe, shown in Figure 1, is basically similar to a conventional slotted line probe, although a motor has been added to make probe travel automatic. As the probe travels automatically back and forth, an associated potentiometer arrangement generates a horizontal sweep voltage for the indicator. The combination of this horizontal sweep and the amplified detector output allows reproduction of the wave guide standing wave pattern on the cathode ray tube. Measurements of standing wave ratio are made directly from the cathode ray picture through a calibrated screen, and indications of relative phase of the pattern are read from a calibrated dial. This type of presentation allows unusually rapid adjustment of radio-frequency components since effects of adjustments are instantly apparent. A number of novel techniques are made possible with the instrument.

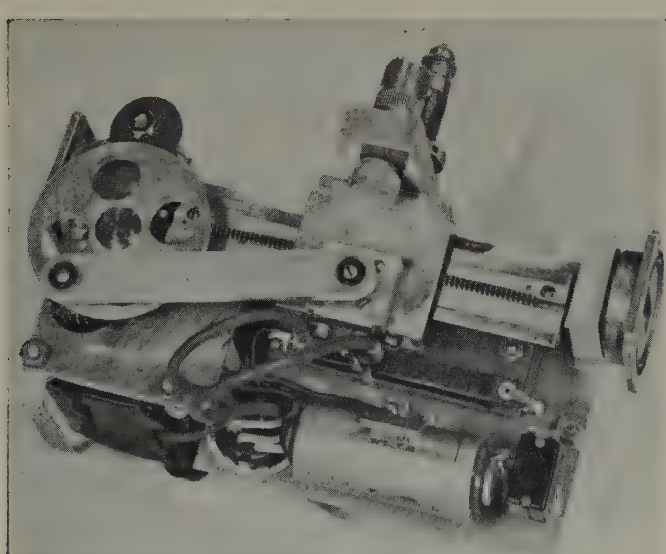


Figure 1. Rear of reciprocating probe showing sweep-generating resistors

Generally, when making standing wave measurements, the time required to determine the effect of an adjustment is frequently much greater than the time required for the adjustment itself, with a consequent inefficient use of time. With the automatic standing wave indicator, however, the effects of adjustments are instantly apparent, hence over-all adjustment time can be cut considerably.

One of the simplest yet perhaps the most valuable applications of the automatic standing wave indicator is in observing qualitatively the effects on the standing wave pattern caused by changes or adjustments made to transmission line components or terminations. For example, the adjustment of a termination for optimum standing wave ratio with the automatic standing wave indicator often can be accomplished in a matter of seconds. The effect of changes is seen immediately on the cathode ray indicator, and adjustments are carried out in the direction of lessening standing wave ratio until a matched condition is reached or most nearly approached. Very frequently this is actually all that a standing wave indicator is called upon to do, as when adjusting tuning stubs, impedance transformers, plungers, line stretchers, or crystal mounts. During this operation, both hands are free to make the adjustments on the component.

Figure 2. Two simultaneous standing wave patterns demonstrating effect of recurrent change in terminating impedance

An unusual capacity of the instrument is its ability to indicate simultaneously multiple standing wave patterns. For example, Figure 2 illustrates two simultaneous standing wave patterns caused by recurrent changes in the terminating impedance. The particular pattern shown was generated by applying a small modulating square wave voltage to a crystal detector termination. The effects of certain types of transmission line switching devices can be observed similarly.

The pictorial presentation of the automatic standing wave indicator makes it particularly suited to illustrate its utility as an instrument for lecture or classroom use in making dramatic demonstrations of standing wave phenomena.

Digest of paper **48-234**, "An Automatic Standing Wave Indicator," recommended by the AIEE instruments and measurements committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Carbon-Pile Voltage Regulator Improvements

B. O. AUSTIN
MEMBER AIEE

H. H. C. RICHARDS

CARBON-PILE voltage regulator concepts are based on controlling the pressure on carbon plates stacked and arranged so that pressure may be applied at right angles to their surfaces. Varying this pressure by predetermined means varies the resistances of the stack. D-c generator field strength often is controlled by the resistance of such a stack to provide output voltage control.

Generally the main design objective for a carbon-pile voltage regulator is to provide an electromagnet with the necessary mechanisms arranged so that the pull curve of the magnet matches the force curve of the spring throughout the operating travel range of the magnet armature properly to control the pressure on the carbon stack.

Carbon-pile voltage regulators similar to the English design by Newton appeared on United States military aircraft early in World War II. This type of a 28-volt regulator has been more successful than other types used. This is caused primarily by the mechanical ruggedness and the ability to withstand momentary overloads. However, they have not been trouble-free and many users have suggested improvements such as longer life, easier maintenance, better temperature compensation, no creeping, no flutter, no overvoltage due to stack wear, minimum hysteresis, minimum friction, and improved provisions for withstanding environmental conditions incident to aircraft operation.

Specification *AN-R-1a* issued by the United States War and Navy Departments outlines many of the objectives desired in the design of an aircraft 28-volt d-c voltage regulator. In the design of such a regulator there are additional objectives which as a rule do not appear in such specifications. It is comparatively easy to design and build satisfactory regulators in the model shop. On the production line it is difficult to maintain the same quality unless the design is adapted to easy accurate methods of obtaining close tolerances and perfect alignment of the vital parts. In addition, carbon stacks and electrodes are wearing parts and must be replaced and the regulator easily reassembled without changing the alignments.

Proceeding with the design improvements of such a regulator there were many factors governing the selection of materials, methods of cooling, springs, magnets, structural details, mountings, and so forth. The carbon stack is governed by such factors as maximum permissible temperature, minimum resistance, maximum resistance, plate dimensions, plate surfaces, grade of materials, and others. Supporting structures are governed by weight, temperature, coefficient of expansion, environment, and other factors. The armature assembly, which is a very important item, is a moving part which requires the proper spring design, low weight of the moving parts, stable materials and so forth.

Digest of paper **48-214**, "Aircraft Carbon-Pile Voltage Regulator, Fundamentals and Design Improvements," recommended by the AIEE air transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

B. O. Austin is section manager and **H. H. C. Richards** is an electrical engineer in the aviation engineering department of the Lima, Ohio, plant of the Westinghouse Electric Corporation.

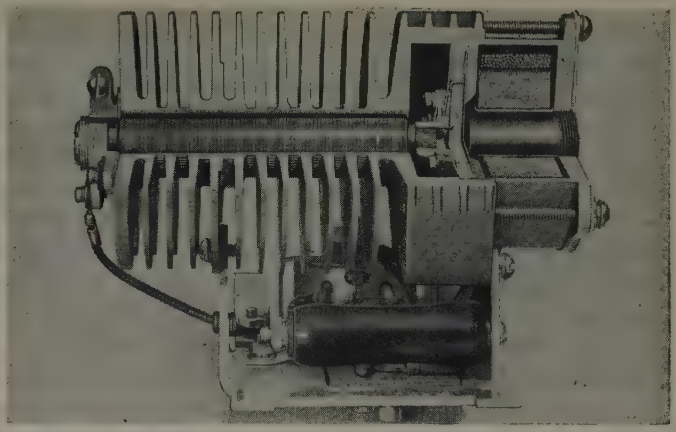

Figure 1. Cutaway view of the carbon-pile voltage regulator

Materials in the magnetic circuit were required to have low hysteresis magnetically and of uniform quality. Cooling methods must be composed of low weight materials and effective means of heat dissipation. Every part of the regulator was required to withstand the environmental conditions to which it is subjected in aircraft service. New structural methods are employed in many of the subassemblies. Figure 1 shows a cutaway view of the carbon-pile voltage regulator designed to the objectives outlined.

Through a long series of test and inspections the following facts were established:

1. Better voltage regulation.
2. Lower operating temperatures.
3. Improved acceleration and vibration characteristics which affect life and regulation.
4. Longer life.
5. Sealed protection against salt spray, sand, and other foreign objects.
6. Good temperature compensation without added details.
7. Friction and creep reduced very substantially.
8. Better performance under high and low ambient temperature conditions.
9. Wearing of parts made readily accessible and replaceable.
10. Reduction in the number of parts.
11. Disassembly and reassembly without change in alignment.
12. Improved armature construction.
13. Dissipates a maximum of 90 watts.
14. Weight increased about two ounces over regulators of 75-watt rating.
15. Design well adapted to production and maintenance of alignment of parts.

Effects of Silicone Vapor on Brush Wear

J. MARSDEN ROBERT H. SAVAGE

THE LUBRICATION of graphite by water vapor is now well known. Many other condensible vapors, however, have been found equally effective. Demonstrations occurred during the high-altitude testing of aircraft brushes during the war. It was found that certain solvents from the freshly painted interiors of cold chambers provided vapor lubrication for brushes operating under dry conditions, and brush dusting which normally would have occurred was prevented. The easily condensible vapors as a class, excepting corrosive substances, thus gradually became recognized as lubricants for carbon brushes.

It was extraordinary in view of this to find in 1945 that the wear rates of carbon brushes were *accelerated*, by a factor of 10 or more, when operated in "totally enclosed" motors having silicone insulation. The high wear could be lowered quickly simply by opening the machine to the normal atmosphere. Silicone-insulated motors which were *not* totally enclosed showed no such trouble.

In a fundamental laboratory study of this problem it was found that in the presence of oxygen and in a confined space methylpolysiloxane vapors accelerate the wear of current-carrying carbon brushes by several fold (and up to 800 fold under the severe conditions of high silicone concentration coupled with high current density). This high wear occurs as a series of intermittent dusting periods, as shown in Figure 1, each lasting for only a few seconds, and each preceded by excessive build-up in the contact

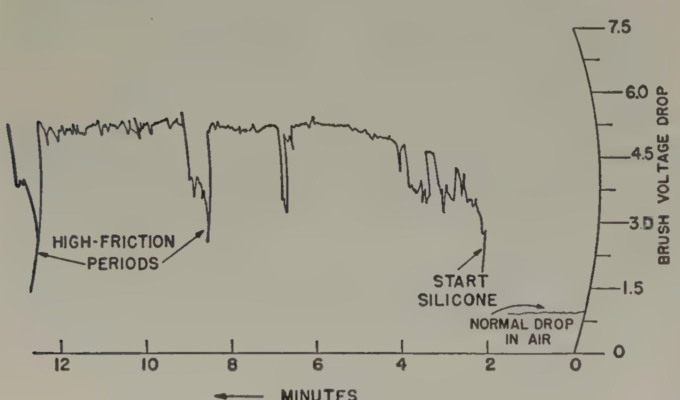

Figure 1. Brush voltage drop in methyl silicone vapor plus air

voltage drop due to an irreversible contamination of the rubbing interface by silicone decomposition products. The momentary dusting period cleans off the insulating layer and exposes fresh surface for a repetition of the build-up and dusting cycle.

The most important step causing this wear apparently is the oxidation of silicone to silica or to a siliceous residue (see Figure 2) which occurs in the high temperature zone of interfacial rubbing contact. In the absence of oxygen, silicone vapor at a pressure of a few millimeters (mercury)

Figure 2. Photomicrograph of brush face showing white masses in the contact zone, after etching

is stable and actually lubricates the graphite, and this lubrication occurs independently of the presence or absence of water vapor.

The vapors produced by heating each of several commercially available silicone resins to the temperature range 175–200 degrees centigrade also caused excessive brush wear, and a parallel study of weight loss of the resins so heated to produce the high wear indicated that the wear is not prevented by a longer term curing of these resins. It was found that the observed weight loss continued even after the curing for a long time at 250 degrees centigrade. This weight loss was due to the removal of volatile fragments produced by thermal decomposition of nonvolatile polymer. This result is important because it shows that accelerated brush wear will persist until the useful insulating life of the resin has been largely destroyed.

Two tentative solutions to the problem are indicated. It was found that brushes impregnated with certain organic liquids which were not silicones, did not wear at an excessive rate in silicone vapor until most of the impregnant had been evaporated from the brush as a result of high temperature operation. From this it is suggested that further work with impregnated brushes may yield a longer term solution to the wear problem. However, the more practical solution appears to be the isolation of the brush system from the silicone vapor which is evolved from the machine windings, and this may be accomplished by means of a separate pressurized compartment in the totally enclosed unit. No accelerated wear problem has been reported to exist in silicone insulated machines which are not totally enclosed and therefore these suggested solutions need be applicable only to the relatively small number of machines in which vapors from the hot insulations are recirculated within the brush ambient region.

Digest of paper 48-211, "Effects of Silicone Vapor on Brush Wear," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Simplified Calculation of Fault Currents

AN AIEE COMMITTEE REPORT

A simplified procedure for the calculation of short-circuit currents was presented in earlier reports [1,2] which has been found to be generally satisfactory. The procedure is intended for general use by the industry as a simplified method of approximating the magnitude of fault currents, however, other more rigorous methods should be used when required. This report brings the previous reports up to date.

THE PRECISE determination of short-circuit currents involves a complicated calculation which in many instances is not necessary. Certain approximations can be made although a degree of judgment must be applied in any simplified method. The method presented is based upon the determination of an initial value of rms symmetrical current with which multiplying factors are used for application purposes. It may be used, where applicable, in place of the methods which involve the use of decrement curves. It is believed that this procedure is sufficiently accurate to serve as a reliable basis for the usual application of interrupting devices and as a preliminary basis for relay settings. A recent review of the procedure revealed the need for certain modifications in order to improve and bring the previous report up to date.

The multiplying factors given in Tables I and II take account of generator decrement and the asymmetrical value of current as influenced by the system d-c time constant, and they are adjusted to make allowance for the increase in generator excitation required to maintain normal terminal voltage under load conditions. They neglect, however, such influences as generator voltage regulators and phase-angle differences between generator rotors, which have but little effect within the usual operating time of modern circuit breakers.

A comparison of the current magnitudes determined by these factors with those determined from decrement curves[4] previously in general use is given in Figure 1. The time intervals selected for comparison correspond to power circuit breaker interrupting time ratings of 2, 3, 5, and 8 cycles, with time from inception of fault to parting of contacts assumed to be not less than 1, 2, 3, and 4 cycles respectively. The fault current and reactances are based on the system kilovolt-amperes. The earlier "decrement curves" gave rms total current, but for purposes of comparison, Figure 1 also includes "a-c component only." The total rms current (decrement curve method) is based on the assumption that for all short circuits the decay of the d-c component of current has a time constant of 0.15 second. However, as this 0.15 second time constant is larger than the values usually encountered in any equipment except generators and reactors, results are often conservative. In the general case, actual total rms currents are no greater than the "simplified method" values indicated in Figure 1. The d-c time constant may be expressed generally as equal to

$(1/2\pi f)\ (X/R)$ in seconds, or

$(1/2\pi)\ (X/R)$ in cycles,

where X is the reactance in ohms at system frequency f and R the d-c resistance to the point of fault.

In this method of determining fault currents, symbols are used with the significance given in the following

E = Phase to neutral voltage

X_1 = Direct-axis positive-sequence reactance, either transient or subtransient as specified, in ohms per phase

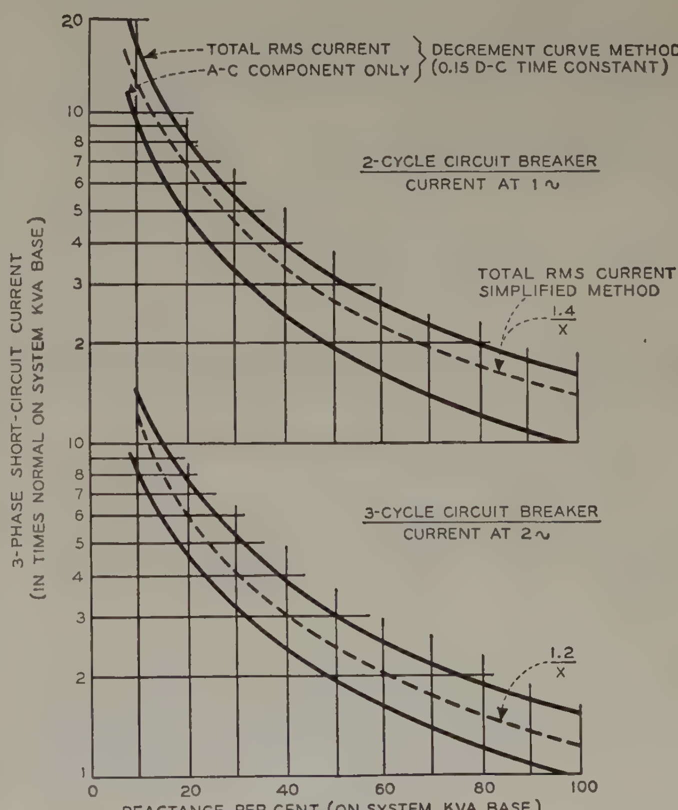

Figure 1A

—— *Decrement curve method*

- - - - *Simplified method*

Full text of "Simplified Calculation of Fault Currents," a revision by a working group of the AIEE switchgear committee of a report originally sponsored in 1942 by the AIEE committee on protective devices and first revised by that committee in 1943.

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X_2 = Negative-sequence reactance, ohms per phase
X_0 = Zero-sequence reactance, ohms per phase
R_0 = Zero-sequence resistance, ohms per phase

The type of fault (number of phases involved, with or without ground) which will result in the maximum fault current varies with the relative values of the different circuit constants.

The 3-phase short-circuit current is E/X_1. The line-to-line short-circuit current is $\sqrt{3}E/(X_1+X_2)$. Since X_2 is usually equal to X_1, this current seldom exceeds 86 per cent

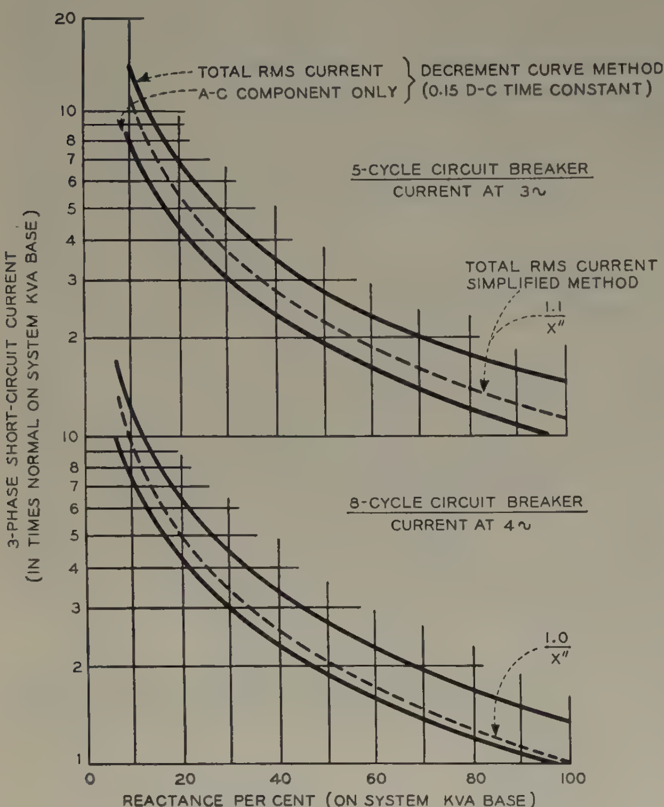


Figure 1B
—— *Decrement curve method*
- - - - *Simplified method*

of the 3-phase short-circuit current, and, consequently, for line-to-line faults the 3-phase fault-current value is generally satisfactory.

The line-to-ground short-circuit current is

$3E/(X_1+X_2+X_0)$

Since X_2 is usually approximately equal to X_1 (using the subtransient value for X_1), this expression often is shortened to

$3E/(2X_1+X_0)$

In practical cases, regardless of the value X_2, this last expression is satisfactory for determining the conductor current in either single or double line-to-ground fault.

PROCEDURE

The following gives a résumé of the procedure and the various multiplying factors to be used with currents calculated by the formulas just stated. Tables I and II show what reactance quantity should be used for representing the machines in the positive-sequence network.

Interrupting Duty. Determine "highest value of rms symmetrical current for any type of fault" by

E/X_1

or

$3E/(2X_1+X_0)$

whichever is greater, except that with resistance grounded systems when R_0 is greater than $2.23X_1$, no consideration need be given to the latter expression

$3E/(2X_1+X_0)$

Use multiplying factors as given in Table I for specific type of apparatus. It has been found that for systems where the 3-phase fault kilovolt-ampere at the generator bus voltage does not exceed 500,000 (before the application of multiplying factors), no additional multiplying factor is required. When calculated values exceed 500,000 kva these multiplying factors should be increased as indicated in Table I, section *A*2, to compensate for the longer d-c time constant of large generators and reactors.

For the application of protector tubes,[3] both minimum and maximum fault currents must be determined. The minimum fault current should be determined on the basis of minimum connected synchronous capacity and symmetrical current using

E/X_1

or

$3E/(2X_1+X_0)$

whichever gives the lower value. Special consideration is required where ground resistance appreciably can reduce this line-to-ground fault current. Protector tubes are rated in terms of symmetrical current but are designed to withstand full asymmetrical current and therefore the multiplying factor is 1.0.

Fuses are rated on total current, and, as the time durations involved are very short, their required interrupting capacity should be based on the total rms current at one-half cycle, using subtransient reactances for both synchronous and induction machines. Two cases should be considered as follows:

1. At 15,000 volts or below, except for current-limiting fuses, when the fuse is located remote from generating stations or primary substations (that is, X/R is less than 4) multiply by 1.2. This is because the rms current of a maximum displaced wave in the first half cycle will not exceed 1.2 times the calculated symmetrical current.

2. In all other cases, including current-limiting fuses, regardless of voltage, multiply by 1.6.

In determining the X/R ratio in the calculation, the entire X value from source of power to the fuse location should be used by the R value only from the fuse back to the first primary substation. The error in neglecting the remainder of R is negligible, and the difficulty in obtaining rigorous values is not commensurate with the increase in accuracy obtained. If the X/R ratio is less than 4, the

lower multiplying factor of 1.2 is permissible; otherwise the factor of 1.6 should be used. Although it is recognized that the same line of reasoning could be applied to higher-voltage fuses which are not current limiting, a survey of many cases indicated that the majority of these cases would fall in the 1.6 multiplier class.

For all current-limiting fuses, the multiplying factor will be 1.6. This is because the rating of such fuses is based on an unsymmetrical current value equal to 1.6 times the symmetrical current.

Mechanical and Momentary Duty. For many purposes, it is necessary to know the maximum possible rms current (including both a-c and d-c components) which can flow in the circuit. Allowing for overexcitation of generators on account of load, the rms value of current as calculated for zero time is about 1.8 times the value calculated by dividing phase to neutral voltage by subtransient reactance. As there always will be some delay even in the first half cycle; however, a multiplier of 1.6 is acceptable.

In some instances, as when transmission line or cable reactance is an important factor in the limitation of current, the factor 1.6 may be higher than necessary. In such applications at 5,000 volts and below, the ratio of reactance to resistance is sufficiently low so that the d-c component decreases very greatly during the first half cycle. Thus within this voltage range, and except where the bulk of the power is supplied by generators at the point of fault, a factor of 1.5 may be used instead of 1.6.

Low-Voltage Systems. Low-voltage air circuit breakers (rated 600 volts or less) are often instantaneous in operation and part contacts during the first half cycle. These circuit breakers, however, are rated on the basis of average current in the three phases, and circuits on which they are installed rarely have X/R ratios exceeding 12. This corresponds to an average rms current at one-half cycle after instant of fault which equals 1.25 times the symmetrical current. Such circuit breakers therefore may be applied on the basis of 1.25 times the 3-phase initial symmetrical current using subtransient reactance and including both synchronous and induction motors.

In calculating the equivalent system impedances, it should be remembered that at low voltages even small impedance values become of importance, and all elements of the circuit, including current transformers, disconnects, switches, bus runs, and their connections, should be taken into consideration.

Overcurrent Protective Relays. In approximating the settings of overcurrent relays, the fault currents for two conditions should be determined:

1. The maximum initial symmetrical current for maximum connected synchronous capacity as determined by E/X_1 or $3E/(2X_1+X_0)$, whichever is greater, except that, when R_0 is greater than $2.23X_1$, no consideration need be given to the expression $3E/(2X_1+X_0)$.

2. The minimum symmetrical current for minimum connected synchronous capacity as determined by $0.866E/X_1$, or $3E/(2X_1+X_0)$ for reactance grounded systems. In particular situations, allowance should be made for remote fault locations and fault resistance.

Ground, distance, balanced, and other types of relays require special consideration.

Table I. Multiplying Factors for Application of Interrupting Devices

	Multiplying Factor	Reactance Quantity for Use in X_1: Synchronous Generators and Condensers	Synchronous Motors	Induction Machines
A. Circuit Breaker Interrupting Duty				
1. General case				
8-cycle or slower circuit breakers*	1.0			
5-cycle circuit breaker	1.1	subtransient**	transient	neglect
3-cycle circuit breaker	1.2			
2-cycle circuit breaker	1.4			
2. Special case for circuit breakers at generator voltage only. For short-circuit calculations of more than 500,000 kva (before the application of any multiplying factor) fed predominantly direct from generators, or through current-limiting reactors only				
8-cycle or slower circuit breakers*	1.1			
5-cycle circuit breakers	1.2	subtransient**	transient	neglect
3-cycle circuit breakers	1.3			
2-cycle circuit breakers	1.5			
3. Air circuit breakers rated 600 volts and less	1.25	subtransient	subtransient	subtransient
B. Mechanical Stresses and Momentary Duty of Circuit Breakers				
1. General case	1.6	subtransient	subtransient	subtransient
2. At 5,000 volts and below, unless current is fed predominantly by directly connected synchronous machines or through reactors	1.5			
C. Protector Tubes				
1. Maximum rating	1.0	subtransient	subtransient	subtransient
2. Minimum rating — use minimum system capacity and minimum of E/X_1 or $3E/(2X_1+X_0)$	1.0			
D. Fuses				
1. At 15,000 volts, or below, except for current-limiting fuses when the fuse is located remote from generating stations or primary substations (that is, X/R is less than 4)	1.2	subtransient	subtransient	subtransient
2. All other cases, including all current-limiting fuses regardless of voltage	1.6			

* As old circuit breakers are slower than modern ones, it might be expected a low multiplier could be used with old circuit breakers. However, modern circuit breakers are likely to be more effective than their slower predecessors, and, therefore, the application procedure with the older circuit breakers should be more conservative than with modern circuit breakers. Also, there is no assurance that a short circuit will not change its character and initiate a higher current flow through a circuit breaker while it is opening. Consequently, the factors to be used with older and slower circuit breakers well may be the same as for modern 8-cycle circuit breakers.

** This is based on the condition that any hydroelectric generators involved have amortisseur windings. For hydroelectric generators without amortisseur windings, a value of 75 per cent of the transient reactance should be used for this calculation rather than the subtransient value.

Table II. Multiplying Factors for Preliminary Relay Settings

	Multiplying Factor	Reactance Quantity for Use in X_1: Synchronous Generators and Condensers	Synchronous Motors	Induction Machines
1. High-speed current actuated	1.0	subtransient	subtransient	subtransient
2. Time overcurrent	1.0	transient	transient	neglect

REFERENCES

1. System Short-Circuit Currents, **W. M. Hanna, H. A. Travers, C. F. Wagner, C. A. Woodrow, W. F. Skeats.** AIEE *TRANSACTIONS*, volume 60, 1941, September section, pages 877–81.

2. Simplified Calculation of Fault Currents. *ELECTRICAL ENGINEERING*, October 1942, pages 509–11; AIEE *TRANSACTIONS*, 1942, pages 1133–5; *ELECTRICAL ENGINEERING*, February 1944, page 65.

3. Protector Tubes for Power Systems, **H. A. Peterson, W. J. Rudge, Jr., A. C. Monteith, L. R. Ludwig.** AIEE *TRANSACTIONS*, volume 59, 1940, May section, pages 282–92.

4. Standard Decrement Curves, **W. C. Hahn, C. F. Wagner.** AIEE *TRANSACTIONS*, volume 51, 1932, pages 353–61.

Electric Power Distribution Systems

Practices and Trends in the United States

AN AIEE COMMITTEE REPORT

In this report the distribution subcommittee of the AIEE transmission and distribution committee has attempted to study and analyze distribution system design practices in the United States and to point out the main reasons for these practices, as well as noting definitely indicated trends and the reasons for them. The report is not intended as an original study of the economic aspects of the problem, but it is hoped that, by presenting a broad picture of American distribution system practices, individual work on such problems will be stimulated and the results of this work will be presented to the Institute in the form of papers.

AN ELECTRIC POWER systemconsists of bulk-power stations, a transmission system, and a distribution system. The bulk-power stations are generating stations and transmission stations. The transmission system consists of transmission lines or circuits which interconnect the bulk-power stations of the system and also the transmission circuits which connect bulk-power stations of the system to bulk-power stations of adjacent electric power systems. These transmission circuits transmit blocks of power between generating stations, from generating stations to transmission stations, and between electric power systems. The distribution system comprises all of the electric power system from the load busses in the bulk-power stations to the consumers' service switches.

The distribution system often is divided into three parts; the subtransmission circuits and distribution substations; the primary system or circuits from the distribution substation load busses to the distribution transformers; and the distribution transformers, secondaries, and services.

Part 1. Subtransmission Circuits and Distribution Substations

SUBTRANSMISSION

The primary function of the subtransmission lines or circuits is to deliver electric power from the bulk-power stations to the distribution substations. Sometimes the subtransmission circuits also serve to transmit power between bulk-power stations and in such cases they serve both as subtransmission and transmission circuits. Subtransmission circuits are in practically all cases 3-phase 60-cycle circuits. The range of subtransmission circuit voltages is generally from 11 kv to 69 kv, with the most widely used subtransmission voltages the generator voltages in the 15-kv insulation class. The trend, however, appears to be to the use of subtransmission voltages in the 34.5-kv insulation class or even higher. Both cable and open-wire subtransmission circuits are used; however, most subtransmission circuits consist of open-wires carried on wood poles. Most of the cable subtransmission is underground in ducts and is in the very large metropolitan areas. A relatively small amount of aerial cable subtransmission is used, and its use appears to be increasing.

The subtransmission circuits may be used to form a number of different patterns or types of systems. The arrangements or types of subtransmission used are radial, loop, grid, and tapped-tie. In many systems a combination of two or more of the four major types or arrangements is used. The selection of the subtransmission arrangement used is influenced by many factors, one important factor being the transmission system employed. Where adequate transmission ties exist between bulk-power stations, radial, loop, or grid subtransmission which does not interconnect the bulk-power stations is very satisfactory. Where transmission ties are inadequate or do not exist, tapped-tie or grid subtransmission which interconnects the bulk-power stations must be used.

Radial Arrangement. The radial arrangement of subtransmission circuits is illustrated in Figure 1. This is a simplified single-line diagram of part of an electric power system used to supply a metropolitan area and the surrounding territory. The three circles marked *B* are bulk-power stations, while *G* indicates a generating station and *T* a transmission station. Generating station 1 is connected to transmission station 2 by two transmission lines indicated by the heavy lines on the figure. Transmission station 2 receives power from a distant hydro generating station over two transmission lines coming in from the southwest.

Essentially full text of paper 48-182, "Report on Electric Power Distribution System Practices and Trends in the United States," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE summer general meeting, Mexico, Federal District, Mexico, June 21–25, 1948; not scheduled for publication in AIEE *TRANSACTIONS*. This report was prepared by the distribution subcommittee of the transmission and distribution committee (C. F. Wagner, *chairman*) for 1947–48.

Personnel of subcommittee: Harold Cole (M '27) The Detroit Edison Company, Detroit, Mich., *chairman;* D. K. Blake (M '39) General Electric Company, Schenectady, N. Y.; T. J. Brosnan (M '34) Buffalo Niagara Electric Corporation, Buffalo, N. Y.; E. R. Hendrickson (M '44) Public Service Company of Northern Illinois, Glencoe, Ill.; J. B. Hodtum (M '26) Allis-Chalmers Manufacturing Company, Pittsburgh, Pa.; D. W. Nethercut (F '45) Ohio Public Service Company, Elyria, Ohio; E. W. Oesterreich (F '42) Duquesne Light Company, Pittsburgh, Pa.; J. S. Parsons (A '27) Westinghouse Electric Corporation, East Pittsburgh, Pa.; R. R. Robinson (A '44) Board of Public Works, Niles, Mich.; F. E. Sanford (F '46) *Electrical World*, McGraw-Hill Publishing Company, Inc., Chicago, Ill.

Transmission station 2 also is connected to generating station 3 by two transmission lines. A single transmission line coming in from the east ties generating station 3 to an adjacent power system. Another single transmission line interconnects generating stations 3 and 1, thus resulting in a ring-type transmission system.

The shaded area represents the commercial section of the city where the load density is high and all electric circuits are located underground in ducts. The squares marked *D* are distribution substations. These distribution substations are fed from the three bulk-power stations over radial subtransmission circuits as indicated by the light solid lines. Most of the distribution substations are fed over two or more subtransmission circuits in order to provide adequate service reliability by preventing an interruption of power supply to a substation when a line fault occurs. Since a fault on one of two open-wire subtransmission circuits on the same pole line often will involve the other circuits also, cable usually is used where it is necessary to install both lines along the same right of way.

Single radial open-wire subtransmission circuits sometimes are used to supply distribution substations as shown in the case of substation 13. Usually these substations are small, serving relatively unimportant outlying loads. A single radial cable feed rarely is used in such cases because of the relatively long time required to locate and repair a fault.

There is one case where single radial subtransmission-circuit supply, either open-wire or cable, commonly is used to distribution substations. This is in the primary network system, where the primary-distribution circuits interconnect the distribution substations on their low-voltage sides as

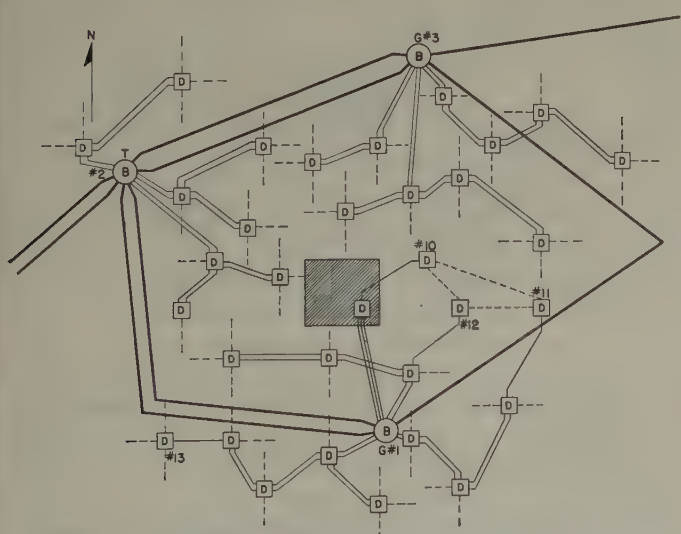


Figure 1. Radial arrangement of subtransmission circuits

shown by the dotted lines between substations 10, 11, and 12. These primary tie circuits provide the necessary emergency supply to the substation load when a subtransmission fault interrupts the normal power supply. All subtransmission circuits feeding the distribution substations in any one primary network preferably should come from one bulk-power station. The primary-network substations 10, 11, and 12 each are supplied from generating station 1 over a different subtransmission circuit. Three distribution substations interconnected on their low-voltage sides to form a primary network represent about the minimum number of substations used in a network. Usually a primary network is supplied through more than three distribution substations; sometimes there are 10 or 12. While the use of the primary network system of dis-

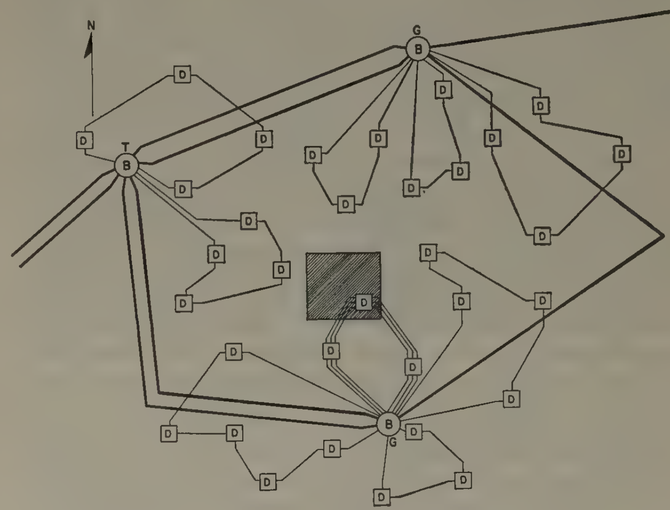


Figure 2. Loop-type subtransmission circuits

tribution is increasing, the great majority of distribution systems use radial primary circuits supplied from the substations, as shown by the dotted lines in Figure 1.

Loop Arrangement. Loop-type subtransmission is shown in Figure 2. The bulk-power stations and transmission lines are the same as in Figure 1. A loop is a closed circuit which has only one power supply point. Two or more loops are run out from each of the three bulk-power stations and each loop supplies three to five distribution substations. The majority are single-circuit; however, a loop may consist of two or more circuits on parallel as shown by that supplying the underground commercial area of Figure 2. Where parallel circuits are used in a loop along the same right of way, the circuits are usually in cable. When using loop subtransmission, each distribution substation is fed over two different lines each of which comes over a different right of way from the bulk-power station. This permits open-wire circuits to provide adequate reliability of power supply to most distribution substations. Most loop subtransmission, therefore, is of open-wire construction. When using either loop or radial subtransmission, the circuits do not interconnect any bulk-power stations. Thus, there is no possibility of transmitting power between bulk-power stations over any subtransmission circuits.

Grid Arrangement. Grid-type subtransmission is shown in Figure 3 interconnecting the three bulk-power stations. This provides a somewhat more reliable power supply to the distribution substations than do the other types of subtransmission, because of the greater number of paths over which power can flow from the bulk-power stations to a distribution substation. The problems of relaying and

power flow through the grid are more complicated than with any other type of subtransmission. As shown in Figure 3, and as almost always used, the arrangement not only provides power supply from the bulk-power stations to the distribution substations, but also provides ties between the bulk-power stations thus functioning also as transmission facilities. Grid subtransmission is the most generally used type. It is found in about three-fourths of the distribution systems in the United States. With this type power flow in the various subtransmission circuits is quite complicated, and relaying problems sometimes quite difficult. The transmission circuits are sometimes in cable, but they are more often of open-wire.

Tapped-Tie Arrangement. Tapped-tie subtransmission shown in Figure 4 is the next most used type. It consists of tie circuits between bulk-power stations, which circuits supply distribution substations along their routes. This arrangement of subtransmission may consist of either cable or open-wire circuits with the latter most used. It provides two paths for power supply to a distribution substation, one from each of two bulk-power stations. The tapped-tie arrangement serves the dual functions of subtransmission and transmission. Power flow in such circuits is complicated by this dual function, but not quite to the extent it is with grid subtransmission. The relaying problem is considerably simpler than it is when using the grid system unless too many distribution substations are fed from one tie circuit. Three to five substations are shown in series in each tie. More than five or six substations in series will result in relatively long fault clearing times or considerably more complicated relaying. The parallels or rings shown in some of the ties permit more distribution substations to be supplied from the tie without necessarily increasing the fault clearing time or complicating the relaying.

The majority of distribution systems use more than one of the types of subtransmission just described. As already pointed out, grid and tapped-tie subtransmission arrangements are the most generally used. There appears to be a trend toward divorcing the transmission and subtransmission functions, and making more use of the simpler radial and loop arrangements.

DISTRIBUTION SUBSTATIONS

The primary function of a distribution substation is to reduce the subtransmission voltage to a lower voltage which generally can be more economically used to deliver power to the distribution transformers. A distribution substation consists of one or more power-transformer banks together with the necessary voltage regulating equipment, buses, and switchgear. In addition to transforming from some 3-phase subtransmission voltage usually between 11 kv and 69 kv to a distribution voltage such as 2,400, 4,160, or 13,200 volts 3 phase, a distribution substation provides voltage regulation and primary circuit control and protection for the area it normally serves.

The design of a distribution substation is affected by the type of subtransmission used to supply it. The greater part of the electric power in the United States is distributed through relatively large distribution substations, usually supplied from grid subtransmission circuits. The use of grid-type subtransmission requires a high-voltage bus in each distribution substation. The cost of such a bus and associated switchgear dictates the use of a relatively large substation, of the order of 10,000 kva to 40,000 kva firm capacity. Distributing such an amount of power from one location makes it necessary to use individual feeder regulation on most or all of the primary feeders.

The most commonly used designs of these large individual-feeder-regulated substations, having both high-voltage and low-voltage busses, are shown in the single-line diagrams of Figures 5 to 9, inclusive. A very popular design is that shown in Figure 5, the design and operating features of which follow.

Design Features

1. Single, sectionalized high-voltage (subtransmission-voltage) bus.
2. Transformer bank connected to each high-voltage bus section through disconnecting switch.
3. Each section of high-voltage bus supplied by a different subtransmission circuit through a circuit breaker.
4. The high-voltage bus sections are connected through automatic circuit breakers, operated normally closed. Differential relaying usually is employed to isolate a section of high-voltage bus and its associated transformer in case a fault develops in either one.
5. Single low-voltage (distribution-voltage) main bus and a low-voltage transfer bus.

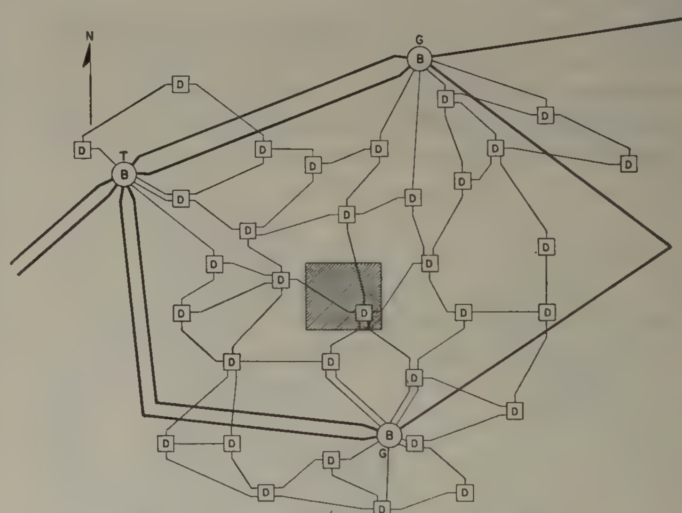


Figure 3. Grid-type subtransmission system

6. Main and transfer busses connected together through bus-tie circuit breaker.
7. Each transformer bank connected to low-voltage main bus through a circuit breaker.
8. Each primary feeder supplied from the low-voltage main bus through a circuit breaker and, in most cases, through reactors and regulators.
9. Two single-phase regulators connected in open-delta usually are used where the primary feeder supply is 3-phase delta. Three single-phase regulators, star-connected, ordinarily are used where the circuit operates 3 phase, 4 wire. Sometimes 3-phase regulators are used.
10. Air-core reactors are used in each phase to reduce the short-circuit duty on the primary feeder circuit breakers and to hold the short-circuit currents through the regulators to safe values.
11. All circuit breakers are provided with disconnecting switches on each side to permit circuit breaker maintenance.

Operating Features

1. Any high-voltage (subtransmission-voltage) circuit breaker can be maintained by taking its circuit out of service. Any high-voltage bus sectionalizing circuit breaker can be maintained by temporarily splitting the bus into two sections. This maintenance work can be done without interrupting service to any load if all circuits and equipment, except that directly associated with the maintenance work remain in service while work is being done.

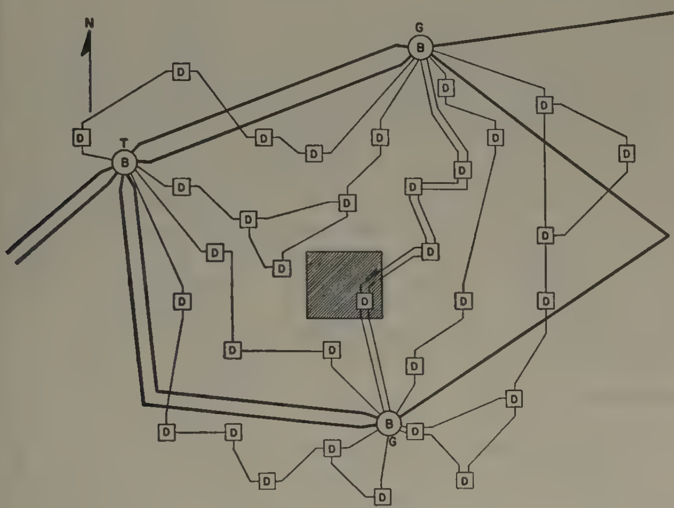


Figure 4. Tapped-tie subtransmission circuits

2. The low-voltage (distribution-voltage) transfer bus is used to maintain individual low-voltage circuit breakers, reactors, and regulators without interrupting service to any primary feeder or having to do switching on the primary circuits external to the substation. The bus-tie circuit breaker temporarily replaces the circuit breaker whose circuit is connected to the transfer bus.

(*a*). When a low-voltage transformer circuit breaker is to be maintained, the main and transfer busses are connected through the bus-tie circuit breaker, the transformer is connected to the transfer bus by closing its disconnecting switch, and the transformer circuit breaker is tripped and its associated disconnecting switches opened. This leaves the transformer circuit breaker completely de-energized, so that it can be maintained safely, and its transformer bank supplying load over the transfer bus and through the bus-tie circuit breaker to the main bus.

(*b*). When maintenance is planned for a primary-feeder circuit breaker, a reactor, or a regulator, the main and transfer busses are connected through the bus-tie circuit breaker; with the regulator control made nonautomatic and the regulator set at the neutral position, the feeder is connected to the transfer bus by closing its disconnecting switch; the feeder circuit breaker is opened; and the disconnects on the supply side of the feeder circuit breaker and the load side of the regulator are opened. This leaves the feeder circuit breaker, reactor, and regulator completely de-energized for safe maintenance, and the primary feeder supplied from the main bus through the bus-tie circuit breaker and over the transfer bus. The transfer from the main to the transfer bus is accomplished without any interruption to the feeder load. While operating from the transfer bus, during the time maintenance work is being done, the feeder is unregulated.

The sectionalized single high-voltage bus shown is the simplest bus arrangement used in these substations. The firm capacity of the substation usually is considered to be that which it can carry safely with one high-voltage bus section, and its associated transformer and subtransmission circuit out of service. This substation has a single low-voltage main bus and a low-voltage transfer bus. The transfer bus ordinarily is designed for only one supply circuit or feeder circuit to be connected to it at any one time.

The substation of Figure 6 is quite similar to the one shown in Figure 5.

Design Features. The design features are the same as for Figure 5 except:

1. High-voltage (subtransmission-voltage) bus is a sectionalized ring.

2. Low-voltage (distribution-voltage) main bus is sectionalized.

3. There is a bus-tie circuit breaker between each main-bus section and the transfer bus, so that any load connected to the transfer bus will be as far as possible independent of the position of the bus-sectionalizing circuit breakers.

4. Each transformer bank is connected to a separate low-voltage main-bus section through a transformer circuit breaker. To simplify the substation and save money, no provision is made for connecting any transformer bank to the transfer bus. This is justified on the basis that the entire substation load can be carried with one transformer bank out of service, and there is very little likelihood of a transformer or high-voltage bus-section fault occurring while a transformer bank is de-energized to permit maintenance of its low-voltage circuit breaker.

Operating Features. The operating features are the same as for Figure 5 except:

1. It is possible to retain connection between subtransmission circuits while equipment is being maintained.

2. All primary feeders are arranged so that they can be transferred from the main to the transfer bus to permit maintenance of individual pieces of equipment just as in the substation of Figure 5. Sectionalizing the low-voltage bus permits emergency maintenance or extension work on a bus section. When emergency work is to be done on a bus section, all primary feeders normally supplied from that section are connected to the transfer bus after the transfer bus has been energized by closing some bus-tie circuit breaker or circuit breakers other than the one associated with the bus sections to be worked on. As soon as the primary feeders have been transferred their bus section can be de-energized completely without interrupting any load by tripping the primary-feeder circuit breakers and the associated transformer and bus-tie circuit breakers. While the bus section is out of service for maintenance or extension work, the entire group of primary feeders is supplied without regulation through one or more circuit breakers in parallel, and, if a fault should occur on one feeder, they all would be de-energized. Sufficient transfer bus and bus-tie circuit breaker capacity, of course, must be provided to permit this emergency work on a main bus section.

Instead of a sectionalized line-type bus, it has a sectionalized ring-type bus which requires one more high-voltage circuit breaker. This type of bus is used where it is important to keep all subtransmission circuits tied together through the bus when maintaining a bus sectionalizing cir-

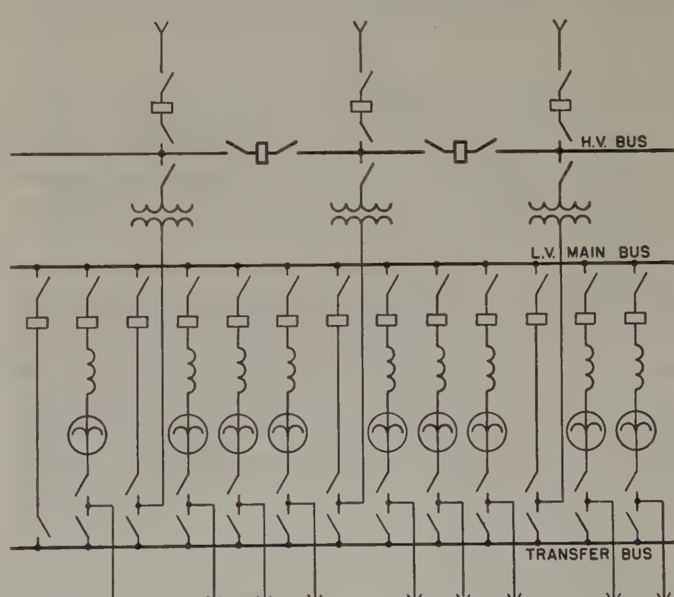


Figure 5. A large distribution substation with sectionalized high-voltage bus and main and transfer low-voltage busses

cuit breaker, and where it is important to maintain the tie between all subtransmission circuits except the one affected when a bus-section fault occurs. This bus arrangement reduces the chances of having the subtransmission grid open up at the station.

This station has a low-voltage main bus and a low-voltage transfer bus just as did the substation of Figure 5. In this substation, however, the low-voltage main bus is sectionalized to prevent an interruption to the entire station load should a bus fault occur. Sectionalizing the bus also permits emergency maintenance or extension work on a bus section. Transfer busses are usually not sectionalized. In a very large substation, however, manual sectionalizing may be provided by means of one or more disconnecting switches. This is done to permit maintenance or extension work to be done on one section of the bus while the other section or sections are used for normal equipment maintenance.

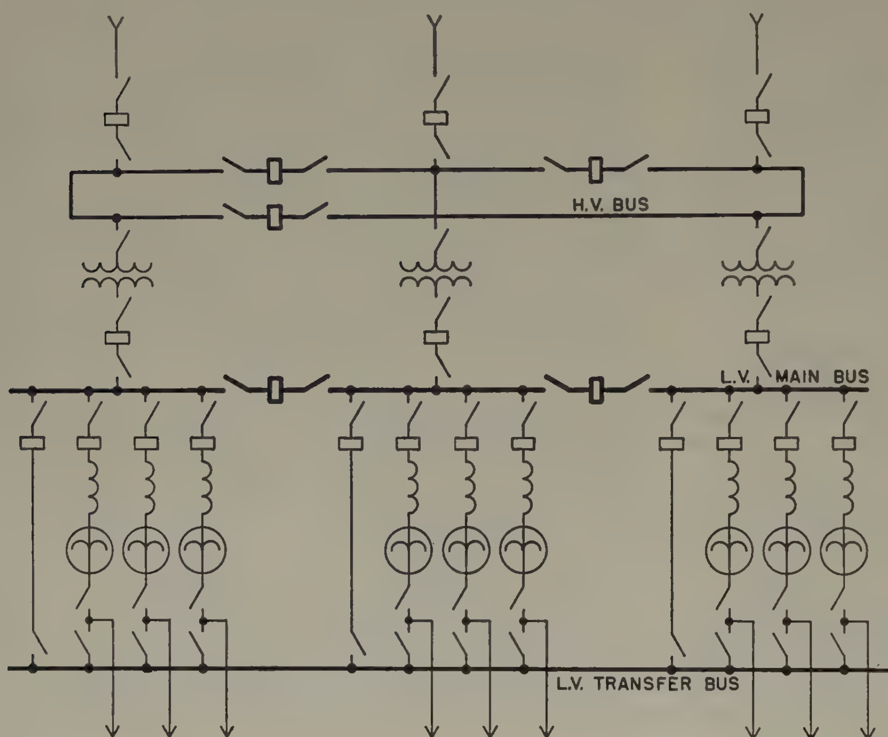


Figure 6. A large distribution substation with ring-type high-voltage bus and sectionalized main low-voltage bus and a transfer bus

Low-voltage transfer busses are quite common in the larger distribution substations, and they occasionally are used on the high-voltage side of a large substation. The substation shown in Figure 7 has a sectionalized high-voltage main bus and a high-voltage transfer bus. The function of this transfer bus is to permit the maintenance of any high-voltage transformer or subtransmission circuit breaker without taking its associated transformer or subtransmission circuit out of service.

A single-circuit-breaker double-bus arrangement with a transfer bus is used on the low-voltage sides of the transformer banks in Figure 7. The use of two main busses permits doing maintenance and extension work on either bus with normal substation connections and protection, rather than with emergency connections and protection as was described in connection with the substation of Figure 6. Having a second or spare main bus available also permits prompt restoration of service to all loads should a main-bus fault occur.

Design Features. The substation shown in Figure 7 has the following design features:

1. Two transformer banks are connected to one main-bus section and only one transformer bank is connected to the other bus section. A second bank may be added to this section in the future. Each transformer bank is connected to a high-voltage main bus section through a circuit breaker instead of through a disconnecting switch as in Figures 5 and 6. Where more than one transformer bank is connected to a high-voltage main-bus section, high-voltage transformer circuit breakers often are used so that a transformer fault will not cause the outage of an entire bus section, and all transformer banks connected to it.

2. In the interest of economy only one bus tie circuit breaker is provided between the main and transfer busses. This should be adequate in view of the small number of bus sections and the relatively small amount of equipment to be maintained. A second bus-tie circuit breaker could be installed and connected between the other high-voltage main-bus section and the high-voltage transfer bus just as was done in the case of the low-voltage busses in Figure 6.

3. Each transformer bank may be connected through a single circuit breaker to either of two low-voltage main busses *A* and *B* by means of two sets of disconnecting switches. Likewise, each primary feeder may be connected through a single circuit breaker to either of the two main busses by means of two sets of disconnecting switches.

Operating Features. The operating features of Figure 7's substation are

1. The high-voltage transfer bus functions just as do the low-voltage transfer busses previously discussed.

2. Normally all transformer banks and all primary feeders are connected to one low-voltage main bus *A* and the other main bus *B* serves as a complete spare bus.

3. The entire substation load can be carried safely with one transformer bank out of service. A transformer low-voltage circuit breaker therefore can be maintained by taking it and its associated transformer out of service.

4. It is not possible to maintain a primary feeder circuit breaker, reactor, or regulator without interrupting the load on the associated feeder during the maintenance period unless transfer facilities are provided. The low-voltage transfer bus, used to permit maintaining any individual primary feeder circuit breaker, reactor, or regulator without any interruption to service, is similar to those previously discussed except that it is arranged to be connected to either of the two low-voltage main bus *A* and *B* through a single circuit breaker by means of two sets of disconnecting switches.

The high-voltage double-circuit-breaker double-bus arrangement shown in Figure 8 is very costly. For that rea-

son it is used only in very large and important distribution substations. This arrangement permits any circuit breaker to be maintained, or either bus to be maintained or extended while using entirely normal circuit and equipment connections and protection.

Design Features. Design features of the substation of Figure 8 are

1. Each subtransmission circuit and each transformer bank is provided with two high-voltage circuit breakers, one for connecting it to each of the two high-voltage main busses *A* and *B*.

2. Modern metalclad switchgear is used on the low-voltage sides of the transformer banks. Physically it consists of two rows of standard single-bus metalclad removable-circuit-breaker compartments connected as shown to the low-voltage sides of the transformer banks, the primary feeders, and the reactors and regulators. The row of switchgear compartments containing low-voltage main bus *A* is complete with removable circuit breakers, and normally the substation is operated with all low-voltage circuits connected to bus *A*. The row of switchgear compartments containing low-voltage main bus *B* is complete except for the removable circuit breakers. A spare removable circuit breaker *S* is provided, which usually is stored in one of the circuit breaker compartments associated with bus *B*.

Operating Features. The operating features are

1. Normally all subtransmission circuits and transformer banks are connected to one high-voltage main bus. The other high-voltage bus and associated circuit breakers are maintained as spares ready for use at any time.

2. This is a single-breaker double-bus arrangement which functionally does everything that a fixed single-breaker double-bus and transfer bus arrangement as shown in Figure 7 will do, except provide feeder regulation when all circuits are transferred from low-voltage main bus *A* to low-voltage main bus *B*.

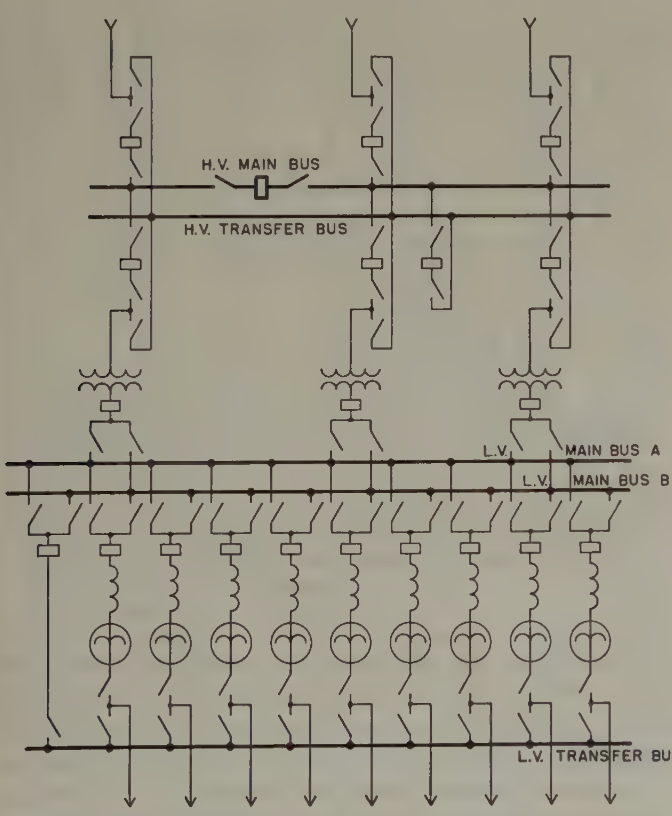


Figure 7. A large distribution substation with both main and transfer high-voltage busses and with a single-circuit-breaker double-bus low-voltage arrangement plus a transfer bus

3. To maintain any low-voltage primary-feeder circuit breaker, it is necessary to insert the spare breaker *S* in one of the *B*-bus circuit breaker compartments associated with one of the transformer banks and close it. Closing circuit breaker *S* energizes low-voltage main bus *B* through the associated transformer bank. Next the transformer bank's normal circuit breaker which is connected to bus *A* is tripped,

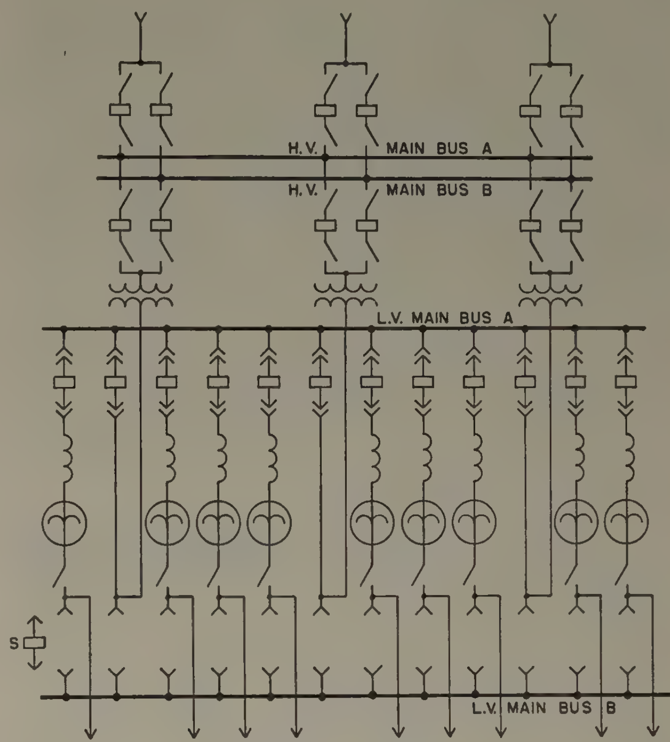


Figure 8. A large distribution substation with double-circuit-breaker double-bus high-voltage arrangement and single-circuit-breaker double-bus low-voltage arrangement using metalclad switchgear

removed from its compartment, and inserted in the *B*-bus circuit breaker compartment which is connected to the circuit breaker to be maintained. This leaves two transformer banks supplying the load connected to the low-voltage main bus *A*. Closing the circuit breaker just inserted in the *B*-bus compartment connects the primary feeder whose circuit breaker is to be maintained to the low-voltage main bus *B*. The feeder's normal circuit breaker now can be tripped, without interrupting service to the feeder's load, and removed for maintenance. If a reactor or regulator is to be maintained, it is necessary to open the disconnecting switch on the load side of the regulator, after tripping the primary-feeder circuit breaker, to isolate this equipment completely.

4. It is preferable to have two spare removable circuit breakers at a substation. This permits all transformer banks to remain connected to bus *A* while one of them also energizes bus *B*. All circuits can be transferred from bus *A* to bus *B* to permit maintenance of bus *A* and then returned to bus *A*, one circuit at a time. Two spare circuit breakers also facilitate this transfer operation, because the loading on the transformer banks does not have to be watched so closely when making the transfer. In this switchgear arrangement low-voltage main bus *B* serves as a transfer bus to permit maintaining individual pieces of equipment without interrupting service to any load, as a spare main bus to permit maintenance and extension work on the normal main bus without any interruption to service, and permits prompt restoration of service to all loads should a fault occur on the normal main bus *A*.

Most of the distribution substations similar to those shown in Figures 5, 6, and 7 use fixed circuit breakers and separately mounted disconnecting switches either located out-

doors or in concrete cells in buildings. Usually the high-voltage switchgear and transformers are located outdoors and the low-voltage switchgear and regulators are located in a building. In the southern part of the United States, however, everything except the relay and control equipment often is located outdoors. For a number of years there has been a definite trend toward the use of both indoor and outdoor metalclad switchgear with disconnecting-type removable circuit breakers where the circuit voltage is below 15 kv. Modern metalclad switchgear is used on the low-voltage sides of the transformer banks in the substation of Figure 8.

The substation of Figure 9 uses two high-voltage busses as did the substation of Figure 8; however, it uses only half as many high-voltage circuit breakers. This design is used where any subtransmission circuit or transformer bank may be taken out of service to permit maintenance of its circuit breaker without seriously overloading any part of the system. The two main busses permit either bus to be de-energized for maintenance or extension without dropping any load, and permit service to be restored promptly to all loads should a bus fault occur.

The low-voltage metalclad switchgear arrangement in this substation is similar to that described in connection with the substation of Figure 8. The only difference is that a full complement of removable circuit breakers is provided in each row of standard single-bus metalclad switchgear. The low-voltage switching arrangement functions just as does that in the substation of Figure 8, except it is unnecessary to transfer circuit breakers from one compartment to another to maintain equipment or transfer all circuits from one bus to the other.

Design Features. The design features of the substation of Figure 9 are the same as for Figure 8 except:

1. Only half as many high-voltage circuit breakers are used with the two high-voltage busses.

2. A full complement of removable circuit breakers is provided with each of the two rows of standard single-bus metalclad low-voltage switchgear. Low-voltage bus *A* is housed in one row and low-voltage bus *B* in the other.

Operating Features. Operating features of this substation are

1. The two high-voltage main busses permit either bus to be de-energized for maintenance or extension without dropping any load, and permit service to be restored promptly to all loads should a bus fault occur.

2. Each subtransmission circuit and transformer bank may be connected to either main bus *A* or main bus *B* through one high-voltage circuit breaker by means of two sets of disconnecting switches.

3. The low-voltage switchgear arrangement functions just as in Figure 8, except it is unnecessary to transfer circuit breakers from one compartment to another to maintain equipment or transfer all circuits from one bus to the other.

There are a large number of distribution substations similar to those just discussed, and illustrated in Figures 5, 6, 7, 8, and 9, in operation in the United States. Most of them were designed and built 20 or more years ago. During the last 12 to 15 years there has been a gradual trend toward the use of smaller and simpler distribution substations. Many of these in recent years have been completely factory-built, and there appears to be an increasing trend in this direction. A number of the more popular and commonly used small and medium size modern distribution substation designs will be discussed. It will be noted that the trend toward the use of the simpler types of subtransmission, such as radial and loop, is reflected in many of these substation designs by the absence of high-voltage busses and a decreased use of high-voltage circuit breakers. There is a marked trend toward the use of 3-phase transformers, and bus regulation rather than individual-feeder regulation. Bus regulation is made practical by the relatively small capacity (usually less than 5,000 kva) of the substations. It ordinarily is provided by means of automatic-tap-changing-under-load equipment on the 3-phase transformers. The most popular sizes of 3-phase transformers used in factory-assembled distribution substations are 1,500 kva and 3,000 kva.

The simple single-feeder types of distribution substations shown in Figure 10 usually are used to supply small towns, rural lines, and small or medium size industrial plants. They also are used frequently on the edges of large substation load areas to relieve bad voltage conditions by taking

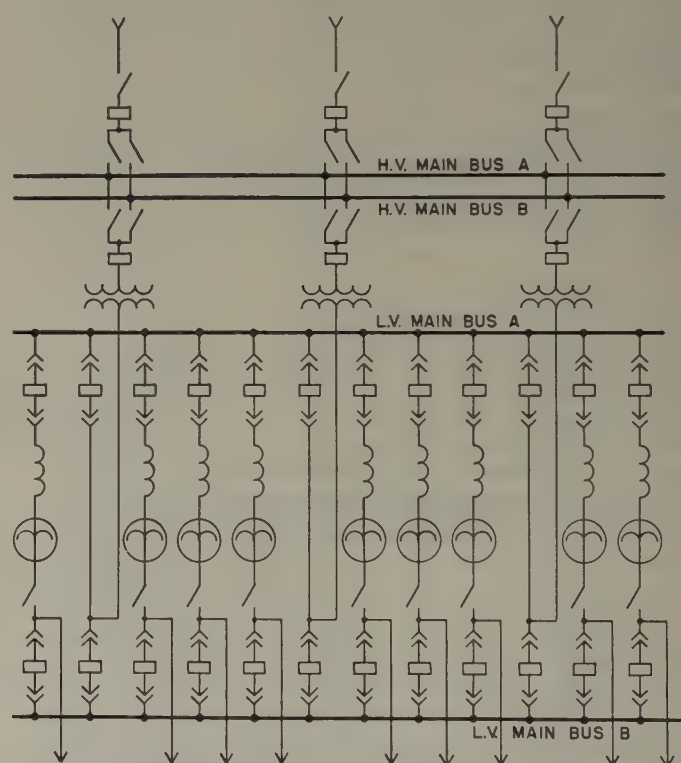


Figure 9. A large distribution substation with a single-circuit-breaker double-bus high-voltage arrangement and a double-circuit-breaker double-bus low-voltage arrangement using metal-clad switchgear

over parts of long heavily loaded feeders and their associated loads. The four substation designs shown in Figure 10 are similar except for the primary switching. Each ordinarily consists of a 3-phase tap-changing-under-load transformer, a disconnecting-type metalclad primary-feeder circuit breaker, a set of high-voltage fuses or protective links, and some form of high-voltage switching. In a more simplified form of this design used for some of the smaller outlying

areas (usually rural in character) single-phase transformers with fuses for both high- and low-voltage protection are used. These usually are not larger than 200 or 300 kva. In some cases service continuity is improved by using a repeating type of fuse or circuit recloser on the low-voltage side.

The substation of Figure 10*A* is supplied through a primary switch by a single subtransmission circuit, either a radial circuit or a radial tap from a loop or tie circuit.

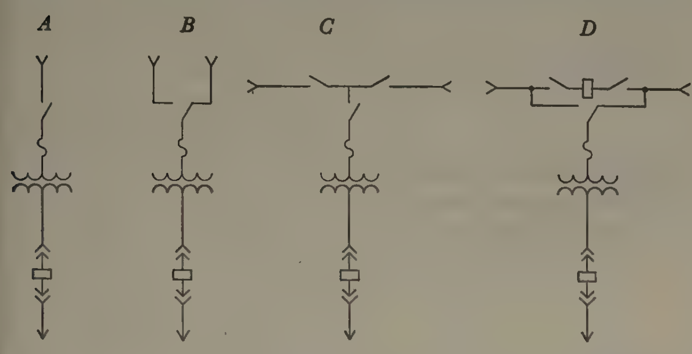


Figure 10. Simple single-feeder types of small distribution substations

This switch is of either the load-break or disconnecting type. When a disconnecting switch is used, it must be capable of breaking the transformer magnetizing current, and it should be interlocked with the primary-feeder circuit breaker to prevent its being called on to break load current. This substation is no more reliable than the single subtransmission circuit which supplies it. To improve its reliability a second subtransmission circuit often is used. The two subtransmission circuits are connected to the transformer through a high-voltage selector switch as shown in Figure 10*B*. One circuit provides the normal supply and, when it fails, the substation is manually connected to the other circuit. The selector switch may be of the load-break type, or of the disconnecting type properly interlocked to prevent opening load current.

The use of two parallel circuits as in Figure 10*B* usually will provide satisfactory normal and emergency supply to a substation, particularly if the circuits are in cable, or, if open-wire, they are on separate pole lines. Thus, when greater than single open-wire circuit reliability is reqired, as is usually the case, two open-wire circuits are taken to the substation over separate routes. Except in the case of very large substations, many distribution substations are supplied in this way from open-wire subtransmission loops or tapped ties. Figure 10*C* shows another common variation of this arrangement. In this case the substation is tapped to a single transmission circuit which is supplied from both directions. By means of manually-operated high voltage air-break switches, the circuit may be sectionalized and service restored over the unfaulted section. The subtransmission circuit may be sectionalized automatically at the substation by means of a high-voltage circuit breaker as shown in Figure 10*D* to prevent a failure of the normal power supply also causing an interruption of the emergency supply. When the normal power supply fails, the substation transformer is connected manually to the other or emergency side of the high-voltage circuit breaker by means by of the high-voltage selector switch. This selector switch is similar to the one described in connection with Figure 10*B*.

The usual primary-network type of distribution substation is shown in Figure 11. It is a single 3-phase transformer bus-regulated substation supplied from one subtransmission circuit. The transformer is connected to a single low-voltage bus. This bus is connected to similar low-voltage busses in other similar primary-network substations by means of the network tie feeders. The tie feeders are connected to the substation bus through primary-feeder circuit breakers. These circuit breakers and the transformer circuit breaker are usually of the metalclad disconnecting type, which permits their being removed quickly from service for maintenance. A transformer circuit breaker always is

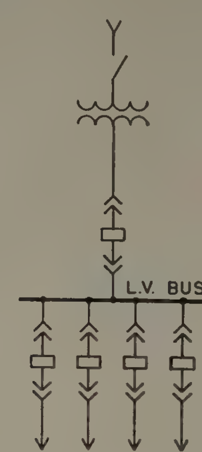


Figure 11. Primary network type of small bus-regulated distribution substation

used in a primary network substation to disconnect a faulty transformer or subtransmission circuit from the system without opening the primary grid.

In a primary-network system any transformer or tie feeder circuit breaker can be removed from service under normal conditions for maintenance without interrupting service to any load. This is because there are normally two paths for current flow to all load taps. The network tie feeders provide the emergency supply to the substation's load when the normal supply is interrupted as may happen because of a fault in the substation transformer or its associated subtransmission circuit. Adjacent primary-network substations are supplied from different subtransmission circuits so that the network tie feeders will function satisfactorily as an emergency supply when a subtransmission circuit is out of service.

The substation design of Figure 11 is used not only in primary-network systems, but it also often is used as a single-transformer radial substation. In such cases the subtransmission supply to it is usually similar to that in Figures 10*B*, 10*C*, or 10*D*. When used in this manner, the transformer circuit breaker sometimes is omitted where facilities exist in the distribution system, external to the substation, which permit the primary feeders normally supplied by the substation to be supplied temporarily from other substations. Transferring the normal substation load to other adjacent substations allows the transformer to be de-energized with little or no interruption to service so that it and its tap-changing-under-load equipment can be maintained. By

transferring load, the circuit breakers also can be maintained without dropping load. The disconnecting-type circuit breakers can be maintained with only a very short service interruption, and without transferring the load to adjacent substations. This is accomplished by removing the circuit breaker to be maintained and immediately replacing it with a spare circuit breaker.

More and more use is being made of portable substations for quick and economic maintenance of these smaller distribution substations. This is due to the increased use of single-transformer bus-regulated substations supplying radial

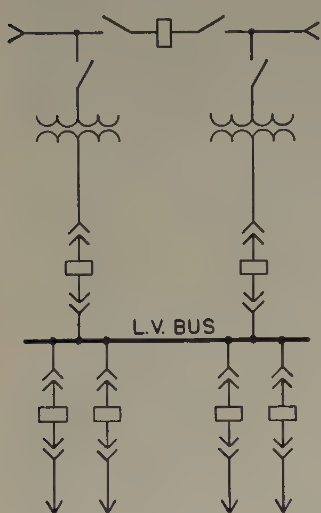
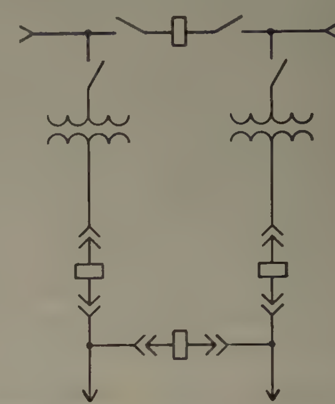


Figure 12. Spot network type of small or medium size bus-regulated distribution substation

primary feeders, the cost of providing the necessary spare capacity and switching equipment in the system to allow transferring load from one substation to another to permit maintenance, and the time and expense required to perform the necessary switching operations. The portable-substation transformer is connected in parallel with the substation transformer to be maintained. The latter then is de-energized for maintenance by opening its high-voltage switch and disconnecting it from the substation low-voltage bus. A transformer circuit breaker is used to disconnect the transformer from the bus. The use of a transformer circuit breaker in a single-transformer bus-regulated radial substation, having two or more primary feeders, facilitates the safe and economic maintenance of the substation transformer and its tap-changing-under-load equipment. It also provides back-up protection for the primary feeder circuit breakers, and simplifies the interlocking of the high-voltage disconnecting switch to prevent interrupting load current.

Another popular type of distribution substation is the 2-transformer bus-regulated substation shown in Figure 12. This spot-network type of substation used in a radial system renders practically the same quality of service as a primary network system. The two tap-changing-under-load transformers normally operate in parallel to supply the radial primary feeders. Usually one transformer is supplied from one subtransmission-loop section or tapped tie section, and the other is supplied from a different section. If the subtransmission supply is from two radial cable circuits, the high-voltage circuit breaker may be omitted. When a transformer or subtransmission-circuit fault occurs, the high-voltage circuit breaker and associated transformer circuit breaker open and disconnect the faulty portion of the system from the substation. The remaining transformer carries the substation load without any interruption to service. The two transformers ordinarily are equipped with automatic forced-air cooling which operates only when one transformer is out of service. The firm rating of the substation is the load one transformer can carry safely over one or two peak load periods with the fans in operation. Either

Figure 13. Small individual-feeder-regulated distribution substation



transformer or transformer circuit breaker can be maintained without any service interruption. The use of disconnecting-type circuit breakers permits the maintenance of any primary feeder circuit breaker with only a very short interruption of its feeder load.

A small individual-feeder-regulated substation is shown in Figure 13. Each transformer is provided with tap-changing-under-load equipment, and the low-voltage tie circuit breaker is normally open. When a transformer or subtransmission-circuit fault occurs, the subtransmission circuit and associated transformer are de-energized. This loss of voltage causes the associated primary-feeder circuit breaker to open, and the tie circuit breaker to close a short time later. Thus, a transformer or subtransmission fault causes only a very short service interruption to the associated primary feeder before it is connected automatically to the other transformer in the substation. When the fault is repaired and the transformer is re-energized, its primary feeder automatically is reconnected. There is a very short service interruption during the reconnection. When a primary-feeder fault occurs, the feeder circuit breaker is tripped due to overcurrent and the tie circuit breaker is not reclosed. Because of the undervoltage relaying used, the primary feeders in this substation cannot be paralleled to supply an industrial-plant or spot-network system.

A medium size or large individual-feeder-regulated substation sometimes is built up by using two or more of the 2-feeder substations just described. Such a station is shown in Figure 14. This station is unique in that it has neither a high-voltage bus nor a low-voltage bus. It can grow to any desired size without increasing the interrupting duty on the primary-feeder circuit breakers.

Another design of distribution substation sometimes used which does not have its transformers paralleled in the station on either their high-voltage or low-voltage sides is shown in Figure 15. The operation of this substation is very similar to that of Figure 13. Each tap-

changing-under-load transformer is supplied from a different subtransmission circuit, and connects to its own low-voltage bus through a transformer circuit breaker. A bus-tie circuit breaker is provided for connecting the two busses. Two rows of standard single-bus metalclad switchgear are used, so arranged that by having one spare removable circuit breaker any primary feeder can be connected to either bus, and the transfer can be made without any interruption to service. Normally the primary feeders are distributed between the busses 1 and 2 so as to secure the desired loading on the transformers, and as nearly as possible the desired voltage regulation on the feeders. The bus-tie circuit breaker is normally open and each bus is regulated independently to secure the best average voltage conditions for its group of primary feeders.

The loss of voltage resulting from a transformer or sub-

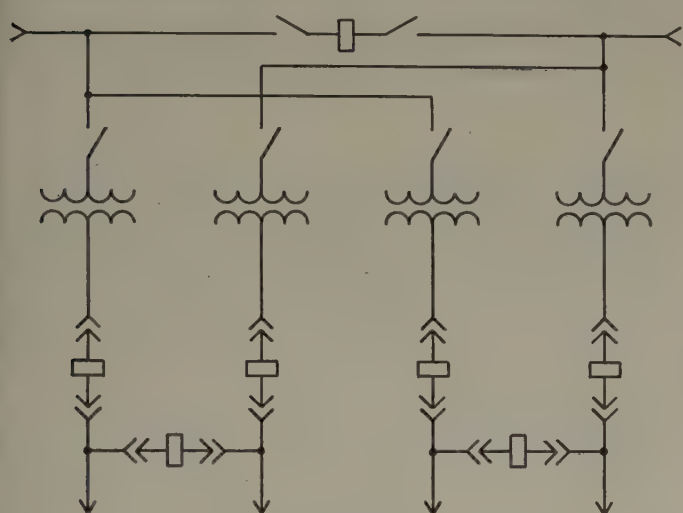


Figure 14. Medium-size individual-feeder-regulated distribution substation

transmission-circuit fault causes the associated transformer circuit breaker to open and the bus-tie circuit breaker to close a short time later. Thus, after a short service interruption the group of primary feeders associated with the faulty portion of the system automatically are transferred to the other transformer in the substation. When normal voltage is restored to the de-energized transformer, the group of feeders automatically is reconnected to its normal supply by the opening of the bus-tie circuit breaker, and the reclosing of the open transformer circuit breaker a short time later. The fact that the transformers in this substation are never paralleled on their low-voltage sides reduces the duty on the feeder circuit breakers. Just as pointed out in connection with the substation of Figure 13, this design is not suitable for supplying secondary network systems.

Figure 16 is a single-line diagram of a very simple individual-feeder-regulated substation. This station has a high-voltage sectionalized bus and high-voltage circuit breakers. It usually is used where the subtransmission voltage is relatively low; that is, below 34.5 kv, and the circuit breaker interrupting requirements do not exceed about 500 megavolt-amperes. This station is made up of a number of single-feeder units, similar to that shown in Figure 10*A*, connected to the high-voltage bus. When using this substation, it is necessary to provide manual switching facilities out in the system to permit sectionalizing and connecting any primary feeder to other feeders. These switches must be operated manually before a transformer and its associated tap-changing-under-load equipment can be de-energized and maintained without a long service interruption.

A spare transformer and low-voltage transfer bus have been added to the substation of Figure 17. Otherwise it is similar to the substation of Figure 16. The spare transformer can be connected to either of the two high-voltage bus sections by means of a high-voltage selector switch. It is connected to the low-voltage transfer bus through a transformer circuit breaker. By means of a spare removable circuit breaker any primary feeder can be transferred from its normal transformer supply to the transfer bus where it is supplied temporarily through the spare transformer. This transfer is made without any interruption to service and frees the associated transformer and feeder circuit breaker for maintenance. Just as mentioned in connection with the substation of Figure 14, the substations of Figures 16 and 17 can be increased to have any desired number of primary feeders without increasing the interrupting duty on the primary feeder circuit breakers.

The substation of Figure 18 is used where service continuity is of great importance and additional circuits or transformers are likely to be added in the future. Each transformer is supplied from a different subtransmission feeder. The transformers are paralleled on their low-voltage sides through switchgear similar to the low-voltage switchgear used in the substation of Figure 8. Normally, both transformers and all primary feeders are connected to

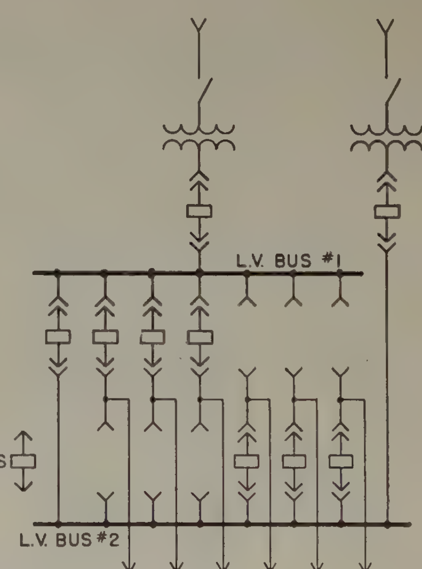


Figure 15. Secondary - selective - type medium-size group-feeder-regulated distribution substation

bus *A;* however, any or all circuits can be transferred to bus *B* without any interruption to service. Bus *B* serves both as a transfer bus to permit the maintenance of any circuit breaker without interrupting service, and as a spare bus to permit maintenance or extension work on either bus. It also allows prompt restoration of service to all loads if a bus fault occurs. It will be noted that the low-voltage portion of this substation is simpler than that of the substation of Figure 8. This is because this smaller substation

uses bus regulation instead of individual-feeder regulation.

Only one of the modern smaller distribution substation designs, Figure 18, uses a double bus. Double and transfer buses which are very common in substations built about 20 years or more ago today are not considered so necessary in distribution substations. This is because of the greater reliability of modern transformers, circuit breakers, and metalclad switchgear; the development of the quickly removable disconnecting type circuit breaker and completely-insulated metal-enclosed bus; the introduction of the primary-network system; and the generally smaller size of distribution substations.

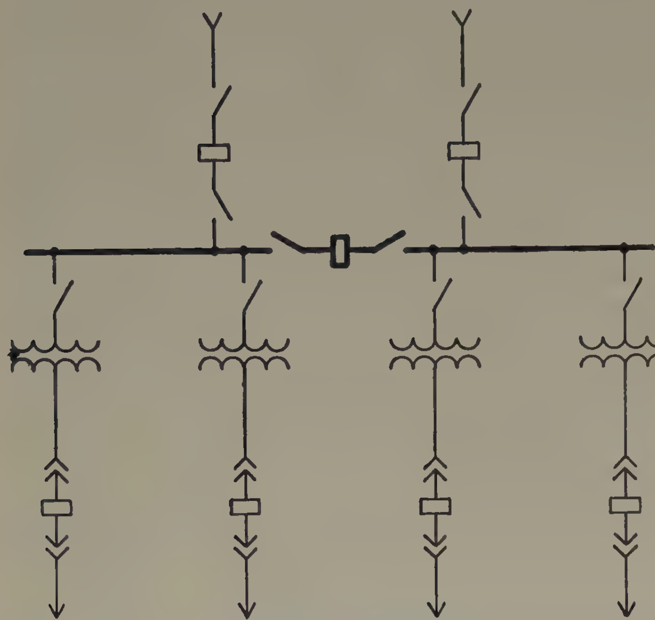


Figure 16. Medium-size individual-feeder-regulated distribution substation with high-voltage bus

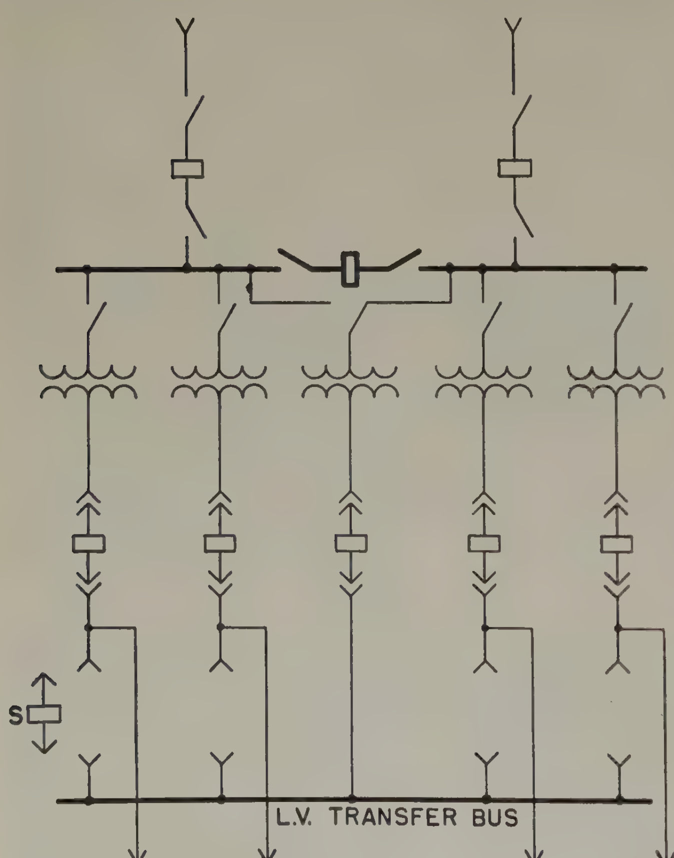


Figure 17. Medium-size individual-feeder-regulated distribution substation with high-voltage bus and low-voltage transfer bus

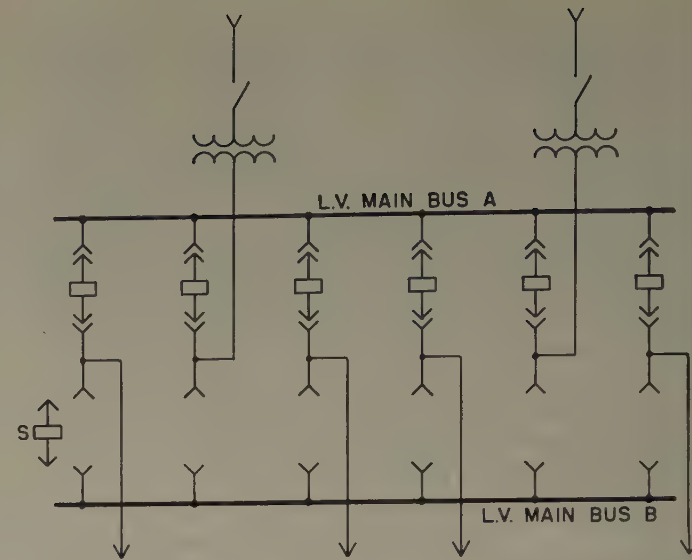


Figure 18. Medium-size spot-network type of bus-regulated distribution substation with spare bus

Part 2. Primary System From the Substation Bus to the Distribution Transformers

FEEDERS

Polyphase feeders from the substation bus to the feed point within the load area to be fed by that feeder are universal in urban and suburban areas. Three phase predominates with 2-phase feeders confined to one large company and a few very small ones. Single-phase feeders are found principally in rural or farm areas.

Sometimes, the feeder is terminated at the first transformer in the area. Other times, it is terminated at a point in the area estimated to be the load center. The former is referred to as the "tree system," and the latter as the "load center system." Choice of these two methods is determined by consideration of voltage drop requirements and physical or geographical conditions within the load area being covered by the mains and laterals.

MAINS AND LATERALS

Mains and laterals to reach the individual distribution transformers overlay the complete load area, and the most common practice is to have all three phases run throughout the area. (Figure 19.) Single-phase laterals are connected alternately to the different phases in order to balance the load. The principal advantage of this method is to get the most benefit from 3-phase distribution and to serve 3-phase power loads often encountered in each circuit area.

The other method is to segregate the phases to form three (or multiples thereof) smaller areas. (Figures 20 and 21.)

Each area with its mains and laterals is single phase. The principal benefits with this method are obtained in connection with banking of single-phase distribution transformers. Another advantage is in the possible improvement of voltage regulation where the load area of the feeder is large and individual-phase regulators may be set for the individual areas supplied by each phase. The gradual return to the practice of banking distribution transformers will tend to increase the practice of phase segregation in residential areas.

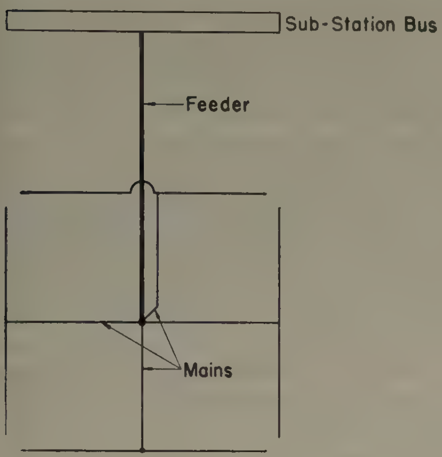


Figure 19

VOLTAGE REGULATION

Automatic voltage regulators commonly are used for adjusting source voltage changes and for feeder drop compensation. The most general practice is individual feeder regulation, but in recent years bus regulation has been adopted for new installations to a considerable extent. Single-phase regulators are the rule for individual feeders and 3-phase equipment (principally tap changing) for bus regulation.

The design and operation of circuits requires a separate consideration of the voltage drop in the feeder and the voltage drop in the mains and laterals. The voltage drop in the feeder is compensated for by means of the regulator in the case of individual feeder regulation.

The voltage drop in the mains and laterals cannot be compensated for. It is the practice to allocate a certain voltage drop, like three per cent, in the mains and laterals between the first transformer and the last transformer. Generally, the mileage of line is several times greater in mains and laterals than in the feeder. This means that a substantial amount is invested in copper to keep the voltage drop within the amount allocated. In the feeder, the voltage drop is compensated for by a regulator at a lower cost than increasing copper size.

This factor of the voltage drop between the first transformer and the last transformer is, therefore, a most important factor in determining the most economical load to carry per circuit. In recent years, this cost has been reduced by the use of pole-mounted branch regulators for long laterals or branches. Shunt capacitors located near the ends of the mains or laterals also have been used widely to produce a voltage rise and thus offset the voltage drop in the mains and laterals. The capacitor gives a voltage rise throughout the entire circuit and is sometimes beneficial in reducing the size of regulator required.

When bus regulation is used, it is not possible to compensate for individual feeder drop as it is with individual feeder regulation. Therefore, the size and number of circuits leaving the substation are determined by the voltage drop from the transformer nearest the substation and the transformer most remote from the substation, even though they may not be on the same feeder. For this reason, bus regulation is practiced where the load density is rather high resulting in short feeders having minor differences in the feeder portion of the circuit. Sometimes, however, feeders

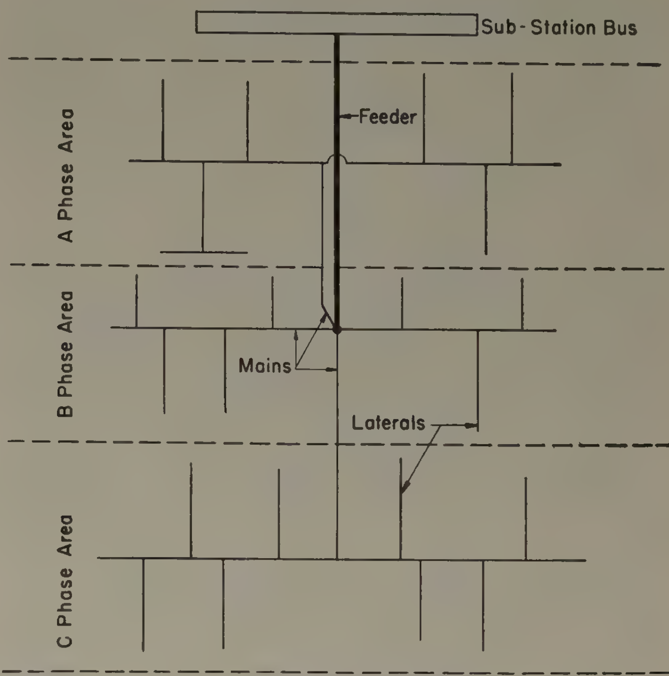


Figure 20

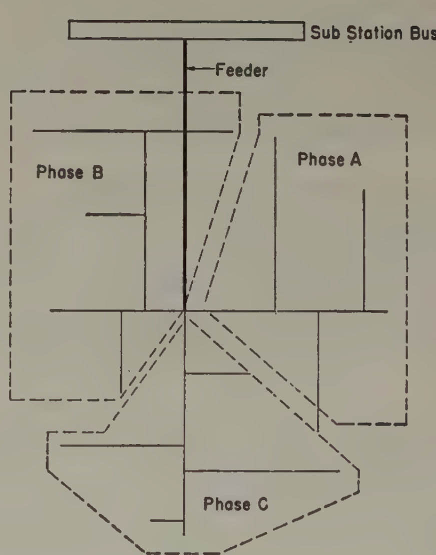


Figure 21

of approximately the same length are grouped together and regulated from the same bus and feeder compensation virtually obtained.

PROVISIONS FOR CONTINUITY OF SERVICE

Increased load per unit length of feeder in general has reduced the feeder lengths and exposure to outage troubles for any given size or rating of feeder. Load growth has combined with improved protection plans to make some economies possible without at the same time reversing the improvement trend in continuity. Thus, larger feeder ratings or the operation of the two former feeders from one circuit breaker position may be possible.

Three-pole circuit breakers at the bus end of the feeder are the general rule. There is a small and diminishing amount of single-pole switching. Automatic reclosing is almost universal. In recent years the practice of immediate first reclosure has contributed to some improvement in continuity. Speeding up reclosing intervals may produce more lockouts where the lines run through trees.

Further improvement has been made in recent years by a more general use of fuses in the mains, laterals, or branches. Benefits from one-shot fuses are dependent on permanent faults (that otherwise would lock out the station circuit breaker) being a substantial percentage of the total. Where this is not so, benefits have been obtained by adding reclosing fuses with two or three reclosures. Successful results with any type of fusing are dependent on careful co-ordination of the time-current characteristics between the various fuses and the station circuit breaker relays.

A further improvement in continuity has been made by selecting fuse and circuit breaker tripping characteristics so the first tripping will be instantaneous and clear the temporary fault before the fuse has had time to reach a damaging temperature. Subsequent trippings have a time delay long enough to allow the proper fuse to clear the permanent fault.

Single-pole circuit breakers closed by gravity and tripped by means of a series coil without the use of conventional relays, called oil circuit-reclosers, have been applied extensively to sectionalize lines, particularly long ones, in the rural areas. They, like the station circuit breakers, also are used in combination with fuses and co-ordinated in a similar manner.

A novel departure from the recloser has been to reverse the process and have the device short-circuit the line during a fault in order to extinguish the arc at the fault and thereby prevent the burning down of the conductor. This requires co-ordination between the time-current characteristics of the short circuiter and the arc-current-burndown characteristic of the conductor. The future extent of its application is not clear at this time, being dependent on operating experience now being obtained.

It is almost universal practice to provide some means for manual sectionalizing of circuits to permit locating faulty sections and to restore service to those sections not in trouble. Where practical, this includes provisions for switching sections of one circuit to a different circuit.

When it is desired to give uninterrupted service to large important consumers, they are given duplicate primary service. The well-known loop and emergency and preferred switching, either manual or automatic, are common ways of providing this duplication. The secondary network system is another means of higher continuity, which is discussed in part 3 of this report.

Diversified motor loads, using automatic starting and stopping, are becoming of increasing importance on many circuits. Outages on these circuits are occasionally long enough so that these motor loads become undiversified when circuits are re-energized. The magnitude of these undiversified loads may be enough to prevent restoration unless corrective measures, such as temporary higher relay settings and sectionalizing means for successively restoring sections, are employed. This condition modifies circuit design to co-ordinate with relay settings and may limit normal load carrying capacity.

Line construction has been modified to reduce outages. The first and most common, for example, is increasing the pin spacing from $14^1/_2$ inches to 29 inches or more. This has reduced the total number of outages in some cases to one-third or one-fourth where trees and wind are major sources of trouble. Self-supporting nonleaded aerial cable is being used on a planned basis by some companies to reduce long outages during sleet storms or hurricanes. It sometimes is used to avoid tree trimming. Other means are improved wire covering and larger minimum wire size. Bare wire is also helpful in preventing burndowns. It is used exclusively in rural areas, and its use in urban areas is increasing where tree conditions permit.

PRIMARY NETWORKS

A substantial number of primary network systems have been placed in operation in recent years. The networks are formed by tying together the ends of mains and laterals of adjacent circuits. The network substations may be thought of as being about the same kilovolt-ampere ratings as a feeder otherwise would be. It is located at the feed point where the feeder would terminate. In this way, the cost of the feeders is saved but is partially offset by the high-voltage subtransmission line to the substation. The principal advantages of this system are to give uniform voltage conditions over the area and uninterrupted load in the event of subtransmission or substation failure. The outages in the event of a fault on the network mains may interrupt more or less load, depending on the corresponding radial system to which it is compared. All outages attributed to the feeders in radial systems, of course, are eliminated. Other aspects of the primary network system have been treated in part 1 of this report.

PRIMARY DISTRIBUTION VOLTAGES

The 2,400/4,160-volt Y 4-wire system continues to be the most common primary voltage. There has been some increase in the 4,800-volt delta systems but not sufficient to establish a trend. Higher distribution voltages, like 13.2 kv, have been commonly utilized to supply industrial consumers of fairly large size. In recent years, 3-phase 4-wire

voltages in this class have become very common for rural areas. There is some trend to a more general use of this voltage class in urban and suburban residential areas. Its economy in urban areas is obtained principally from the elimination of a transformation and in rural areas by its distance covering advantage. In spite of its economy, it has not been very popular in urban areas owing to questions pertaining to telephone co-ordination, live line maintenance, and clearance from trees and buildings.

COMMON NEUTRAL

Multigrounding of the neutral has become very common in the industry. This is tied in with the use of the multigrounded primary neutral in common with the secondary system neutral in those areas where the two neutral conductors otherwise would be located on the same structure, thus reducing the number of conductors with its consequent saving and simplification.

RURAL LINES

There has been a very considerable expansion of lines into rural territories. Single-phase lines greatly predominate. Economy has been obtained principally by using higher strength conductors permitting longer spans and fewer poles than common in urban areas. About 400-foot average spans seem to be very practical and give substantial savings in pole structures. In areas not subject to heavy loading, greater span lengths are practical and economical. Further economy has been obtained by omission of crossarms and using ridge pins for the phase wire and clamping the multigrounded neutral wire to the pole. The great length of these lines calls for ingenuity in maintaining good voltage and providing for continuity. More recognition is being given to the need for good service in these areas.

STREET LIGHTING

No significant change has occurred in series street lighting supply systems since the introduction of the pole-type constant-current transformer. There has been a tendency to use 20-ampere series circuits in the commercial areas where the use of large lamps predominate. This represents a change in practice by omitting the 6.6 to 20-ampere series transformer. Multiple lighting in these areas also is increasing in use. There is also an increasing interest in the economics of multiple street lighting for expansion or replacement of the conventional series system. This is due in part to the increasing difficulty of finding pole space for mounting of control switches and constant-current transformers in many areas. Elimination of a separate feeder for series street lighting permits better utilization of crossarm space.

Part 3. Secondary or Utilization Voltage System From the Distribution Transformer to the Service Entrance

The primary, or high-voltage winding, of the distribution transformer is connected to the primary voltage distribution system outlined in part 2. The secondary, or low-voltage winding, to the utilization voltage system.

The utilization voltage systems are predominantly 120/-240-volt 3-wire single phase, from which both 120-volt lighting and single-phase power connections are made. Three-phase utilization voltage systems are usually 240-volt or 480-volt 3-wire delta for power loads, although 120/208-volt star 4-wire systems are common for combined light and power service in metropolitan areas where lighting loads predominate. Where a small lighting load is supplied from a power system, the mid-tap of one phase of the 240-volt delta system sometimes is used to obtain both lighting and power service from a 3-phase 4-wire system.

THE DISTRIBUTION TRANSFORMER

The distribution transformer is an oil-cooled 2-winding unit, the mechanical and electrical features of which have been standardized by the joint co-operation of the transformer manufacturers and the operators. This standardization, including such features as simplified pole mounting and terminal connections, permits interchangeability of units furnished by various manufacturers. Further standardization establishes nominal voltage classes and the power frequency and impulse levels, which permits co-ordination with protective devices.

All single-phase transformers have two primary terminals, except ratings up to 25 kva in the 7,200 and 7,620-volt classes which may have a single primary bushing for use on grounded neutral systems. The primary terminals are usually of the stud bushing type equipped with mechanical connectors. The connections to the phase wires of the primary voltage system generally are made through external fuses at the transformer.

The trend for the selection of fuse sizes is toward the protection of the primary system against interruption due to transformer failures rather than protecting the transformer against damage due to overcurrents. This results in the application of fuses having higher time-current characteristics than those formerly used.

When the standard transformer is used, the lightning arrester usually is installed on the structure supporting the transformer and is connected to the primary circuit on the line side of the transformer fuse so that lightning discharge currents will not pass through the fuse. In order to obtain a higher degree of protection against lightning damage to the transformer the arrester is installed as close to the primary terminals of the transformer as feasible. Interconnecting the arrester ground lead with the secondary neutral and tank, either directly or through gaps, controls the transient voltage conditions which otherwise may exist during lightning discharge conditions, and thereby limits the transient voltages to predetermined values. The selection of either the solid or gapped interconnection is determined by the effectiveness of grounding on the utilization voltage system.

Factory-assembled transformer units incorporating overcurrent and lightning protection as integral parts of the assembly are being used to simplify the field installation. Such units further incorporate an internally-mounted thermally-actuated secondary circuit breaker which also controls a signal lamp to indicate when the transformer temperature approaches a value which would result in a

circuit breaker operation. Protection to the primary voltage system is obtained by means of an internal overcurrent element having time-current characteristics materially greater than those of the secondary circuit breaker. Units of this type are particularly applicable to single-phase installations.

In some of the rural areas there is a trend toward the use of lightning protection consisting of an external protective gap between the high-voltage bushing terminal and the tank of single bushing transformers. When such transformers are used, they must be connected to primary voltage circuits equipped with reclosing circuit breakers, usually installed in the primary laterals.

UTILIZATION VOLTAGE SYSTEM

In most cases each transformer supplies a separate 120/-240-volt 3-wire circuit, the neutral of which is grounded at the transformer and, in addition, at each service entrance. Such systems supply 120-volt lamps and small 120-volt or 240-volt single-phase appliances.

3-PHASE TRANSFORMERS

The use of 3-phase, transformers for power service is increasing. As in the case of the single-phase units, mechanical and electrical standards have been established in ratings 500 kva and smaller, 15 kv and below.

PARALLEL OPERATION

Parallel operation or banked secondaries appears to be increasing. Such operation may be accomplished by any one of several methods.

(*a*). *Common secondary mains, with each transformer fused on both the high-voltage and low-voltage sides.* With this type of secondary bank, the load normally supplied by any one transformer is automatically picked up by the transformers supplying the bank when a transformer supply is interrupted. In cases where the load on the bank approaches the fuse ratings, the additional load placed upon the remaining transformers may cause successive fuse operations until the entire secondary bank is de-energized. In order to re-establish service to the bank in that case, it is usually necessary to de-energize the primary supply in order to replace the fuses.

(*b*). *Transformers fused on the high-voltage side only, but with fuses connected in the secondary mains between transformers.* A fault in the transformer or the secondary main blows the high-voltage fuses and the secondary main fuses on either side of the transformer. The fuses in the secondary main should be large enough and so located that they will not blow due to normal current flow between sections. They should blow only when a fault occurs in the section of mains between them, or to the transformer feeding that section.

(*c*). *Thermally-operated secondary circuit breakers mounted within the transformer tank.* In such systems the secondary circuit between two transformers is protected by one circuit breaker in each adjacent transformer. Secondary main faults result in interrupted service in the faulted section of the mains without losing transformer capacity. For a transformer failure, the service in the bank is not interrupted unless the load on any transformer results in overtemperature in any of the remaining transformers.

REGULATION

Systems usually are designed so that the maximum voltage variation at any service entrance does not exceed ten per cent. At the transformer rating, the usual allowances for the purpose of design are given in the following table.

	Urban Area (Per Cent)	Suburban Area (Per Cent)	Rural Area (Per Cent)
Transformer	2.5	2.5	2.5
Secondary Main	3.0	2.0	0
Service Drop	0.5	0.5	0.5
Total	6.0	5.0	3.0

To this must be added the primary system drop from the first transformer on the circuit to the last one, which is in the order of three per cent for urban circuits and up to six per cent for rural circuits. Secondary mains rarely are used in rural distribution; the drop usually allowed for secondary mains may be allocated to the primary circuit to permit primary extensions over the greater distances involved in rural territory. The remaining one per cent is allowed for tolerance in the automatic voltage regulating device.

SYSTEM DESIGN

Most systems select a standard size of conductor for the secondary mains for general use in urban areas. Transformers are spaced so as to keep secondary voltage drops within allowable limits for the load densities to be expected in the area. If the load development is below the normal rate of growth anticipated, small transformers are installed first and replaced with larger ones as loads increase. If the load increases to the point where secondary voltage drops are excessive, additional transformers are installed and the length of secondary mains reduced. Exceptions to this practice are made in heavy commercial areas and in thinly-populated suburban and rural areas.

VOLTAGE FLICKER

Voltage flicker usually is caused by excessive starting currents to motor-operated appliances on 3-wire secondary mains. Corrective measures which may be used when such starting currents cannot be avoided are: larger transformers; larger secondary wires; shorter secondary runs; banking of transformers; or the installation of autotransformers at the ends of secondary runs to carry the 120-volt starting currents on the 240-volt circuit. The banking of transformers is usually the most economical method to use where conditions are favorable.

Most systems control the flicker problem by limiting the size of single-phase motors which may be connected to the mains. For radial mains the usual limit is approximately a 1/2-horsepower motor at 120 volts, or a 1-horsepower motor at 240 volts for infrequently started motors, and lower values for automatically started motors which may come on during lighting hours.

LIGHTNING ARRESTERS

Lightning arresters fall into three general classes, all three of which are being used: valve type, expulsion gaps, protective gaps.

(*a*). The valve-type arrester in general has a lower impulse breakdown voltage than the other two. The impedance drop of the arresters, however, may exceed the impulse breakdown voltage for heavy surge currents. Such arresters pass practically no power frequency current.

(*b*). The expulsion gap type has a somewhat higher impulse break-

down voltage with practically no impedance drop. They do, however, allow power frequency current to flow until the first current zero is reached.

(c). In general, the protective gap has an impulse breakdown voltage higher than the expulsion arrester and has no ability to arrest the flow of power frequency current and, therefore, must be used on circuits equipped with instantaneous-trip reclosing circuit breakers.

MAIN AND SERVICE DROPS

Practically all secondary mains are three wire and often are installed on vertical racks attached to the side of the pole. There is a trend toward the greater use of 3-wire service drops and toward multiconductor cables for these service drops. The watt-hour meter usually is installed outdoors at the point where the service enters the building.

SECONDARY NETWORK SYSTEMS

The secondary network is considered the standard distribution system in the heavily-loaded metropolitan areas of the larger cities. In this system the secondary mains, usually underground, are connected together solidly to form a network grid from which services are taken. The grid is supplied from a number of high-voltage feeders usually from the same generating station bus through network transformers and network protectors to the grid. The transformer connections are so arranged that adjacent transformers are supplied from different high-voltage feeders.

Should a fault occur on a high-voltage feeder, or in one of its associated network transformers, the station end of the feeder is disconnected from the system by the tripping of the feeder circuit breaker. Backfeed from the grid, through all of the network transformers connected to the primary feeder, causes all network-protectors of that feeder to open; thus isolating the faulted primary feeder from the grid system without interruption on the grid. The greater the number of primary feeders the less the grid is affected by the loss of any one primary feeder. Such a system gives the greatest possible service continuity.

NETWORK TRANSFORMERS

The network transformer differs from the distribution transformer in that it includes special features considered necessary for network operation. The transformers are usually of 3-phase construction and include a high-voltage grounding switch. The design is very compact to conserve space in underground or building vaults and provides for operation when submerged. They are usually oil-insulated, but for certain locations they may be filled with a nonflammable liquid. Dry-type units are now in limited use.

The most popular rating is 500 kva, 3 phase, while the trend is towards larger ratings. The most popular low-voltage rating is 120/208 volts Y, although there are 480-volt Y and 600-volt Y systems in isolated "spot" networks serving power loads.

NETWORK-PROTECTOR AND LIMITERS

The network-protector is a specially designed 3-pole air-circuit breaker for operation on a secondary network system. The closing and tripping of the circuit breaker is controlled by a set of network relays. The relays cause the switch to close when the voltage across the circuit breaker is such that power will flow from the transformer into the grid when the switch closes. The tripping circuit functions only when the power flow is from the grid into the transformer, even when the reversed power is only due to the magnetizing current of the transformer. The circuit breaker does not open on overcurrent from the transformer into the grid but allows the transformer to supply the current to burn clear secondary-main faults.

Limiters are high-capacity fusible sections installed in the low-voltage grid at each end of the mains and at points where services are taken from the mains. The blowing characteristics are such that they will blow before the insulation on the secondary cables seriously is damaged.

Faults in the secondary mains which do not burn clear will be interrupted at the limiters, thus tending toward reducing the damage to the secondary cables and reducing the generation of gases which could cause manhole explosions.

Among the numerous advantages of the network system are its high degree of service continuity, improved voltage regulation, elimination of costly substations, increased safety for workmen, and the fact that it is the most economical system in the densely-loaded areas.

"Dry" Plating Process

A process of metal plating by means of a gaseous medium has been successfully developed by The Commonwealth Engineering Company of Dayton, Ohio. Heat is the sole means of deposition in the gas-plating process, which involves the thermal decomposition of metal carbonyls in an inert atmosphere of carbon dioxide.

Objects to be plated are radiant-heated in a plating chamber supplied by a metal carbonyl generator, in a closed system which recycles the plating gases for economy of operation. An integral metal coating is quickly obtained at temperatures of approximately 400 degrees Fahrenheit, and the "dry" process is applicable to any material which will withstand this temperature range. Rate of uniform deposition is far higher than that of conventional electroplating, and irregular surfaces, complex shapes, and articles with internal areas are readily handled.

The process is ideally suited to the continuous plating of strip moving at fairly high speeds. In a laboratory test operation utilizing a small experimental unit, 13 pounds, 6 ounces of nickel was deposited in a 60-minute, single-pass plating cycle. In another operation on continuous strip an amount of metal which would have required 30 minutes to apply by conventional plating methods was deposited in four seconds.

Carbonyls of a number of metals, including nickel, iron chromium, tungsten and molybdenum, may be used in the process. Surface preparation for gas plating is the same as for electrolytic plating. Control of the process is relatively simple, however, without the complicating factors of complex baths, delicate solution balances and intricate electrodes presently involved in wet plating.

Digests of Conference Papers of AIEE Pacific General Meeting

These are authors' digests of most of the conference papers presented at the AIEE Pacific general meeting, Spokane, Wash., August 24–27, 1948. The papers are not scheduled for publication in AIEE *PROCEEDINGS* or AIEE *TRANSACTIONS.*

Analysis of Nonlinear Control Systems With the Analog Computer; *G. D. McCann, C. H. Wilts (California Institute of Technology, Pasadena, Calif.).*

Many types of servomechanisms have nonlinearities of sufficient importance that their effects should be considered in analyzing system performance. Some of these nonlinearities are in the control system itself. Others are in the equations specifying the system to be controlled. In position-type controllers, nonlinearities are commonly in the form of velocity or position saturation effects or limits, backlash, coulomb friction, or servos of the "on-off" type. Saturation effects such as occur in motors and generators of speed controllers and voltage regulators are often important.

The nonlinearities existing in the systems to be controlled may be of many types. In mechanical systems they may be in the form of nonlinear damping factors or spring constants or they may be in the form of limits to certain motions being controlled. Certain thermal processes are inherently nonlinear. For certain types of autopilot problems, the nonlinearities in the aerodynamic equations need to be considered.

Suitable multipliers and nonlinear function devices now have been developed for the California Institute of Technology's electric analog computer to enable its use for the rapid solution of a large number of problems of this type. The nonlinear functions include certain rather simple voltage and current limits and devices for generating perfectly arbitrary functions of the dependent variable. During the past year the computer has been used quite extensively for the computing of nonlinear problems, particularly in the field of autopilots.

A general study has been made of the performance of pneumatic and hydraulic servo motors, which shows that the analysis of such systems by linearized equations often leads to designs which would produce complete instability in actual flight performance. However, stability usually can be obtained in such systems by the proper adjustment of the anticipation damping factors or through the use of relatively simple input computer circuits. Saturation effects in voltage regulators or speed control systems seldom result in decreased stability but frequently have important affects on rates of response and steady state errors. The nonlinearities which exist in certain types of mechanical or thermo systems being regulated result in instability when servo design is based upon linearized equations. It is of interest that some of these systems can be stabilized by introducing proper nonlinearities in the control system feedback circuit.

Radio for Telephone Service on the Pacific Coast; *A. P. Hill (Southern California Telephone Company, Los Angeles, Calif.).*

The objective of this paper is to describe the various usages which The Pacific Telephone and Telegraph Company makes of radio in giving telephone service on the Pacific Coast.

The various applications may be listed as follows:

1. Coastal harbor service to ships at sea and to airplanes in flight.
2. Point-to-point service between locations where service by wire lines would be difficult or impractical.
3. Urban mobile service to vehicles in and around city areas.
4. Highway mobile service to vehicles on main arterial highways.
5. Emergency service made necessary by interruptions to normal wire services due to storms, major disasters, and the like.
6. Television service.

In regard to coastal harbor service, the whole Pacific Coast from Seattle to the Mexican border is covered completely by six radio stations; the Southern California station near San Pedro frequently communicates with fishing fleets 1,500 miles to the south. A number of airplanes also have access to the regular telephone system through these stations.

Examples of point-to-point service are from Timberline Lodge on Mount Hood to Portland, Los Angeles to Catalina Island, and Specter Mountain to Death Valley. This latter application avoids the necessity for rebuilding and maintaining 60 miles of pole line over extremely difficult terrain where the temperature rises as high as 130 degrees.

Urban mobile service now is being given in the major cities of the coast and there is urgent need for its expansion as soon as additional frequency assignments are available. In the Los Angeles area, in addition to serving ordinary passenger automobiles, service is being given to school busses, street lighting repair trucks, county ambulances, Southern Pacific Railway switching engines, three city garbage trucks which pick up 300 to 400 dead animals of all sorts per day, and so forth.

Highway mobile service is planned to cover the major Pacific Coast highways. Certain sections of these roads are now covered and work is proceeding on additional coverage as rapidly as possible.

For emergency service, emergency equipment is held at a number of strategic points along the coast so that, in the event of interruption to regular service due to any cause, gaps may be bridged as rapidly as possible.

For television service, arrangements have been made to provide television radio links between broadcasting studios in Hollywood and Mount Wilson, at which point a number of television transmitters are to be located. As an example, service from the National Broadcasting Company studio in Hollywood to the transmitter on Mount Wilson will open shortly by means of polyethylene cable pairs from the studio to the Hollywood telephone office and thence by an already tested radio link to Mount Wilson.

High-Voltage Distribution System in Spokane; *Earl Baughn, E. G. Peters (The Washington Water Power Company, Seattle, Wash.).*

For the last nine years, the Washington Water Power Company has provided for load growth on its overhead distribution plant in the city of Spokane by installing 13-kv Y-grounded radial feeders. These feeders are connected to the high-capacity 13-kv subtransmission network in the city by means of regulating stations consisting of a 5-per-cent 125-ampere reactor to limit the short-circuit current on the feeder; a 600-ampere reclosing oil circuit breaker of 50,000-kva interrupting capacity; and a 125-ampere 10-per-cent buck or boost step voltage regulator; together with suitable disconnecting and by-passing air switches. A complete single circuit installation is nominally rated at 3,000 kva, with a short-time winter peak rating of approximately 4,500 kva.

The installation of these 13-kv feeders has required considerable rebuilding of existing overhead lines as well as new construction for extensions. In the construction of such pole lines, the aim has been to make the structure as simple and economical as reliable operation would warrant. To do this, a pole or ridge pin has been used for the one-wire single-phase primary circuits. Two-phase conductor or 3-phase conductor circuits are installed on crossarms. Because of the inherent high load carrying capacity of a 13-kv system, and because less than five per cent of the load served is 3 phase, a preponderance of single primary wire construction is used.

Low-voltage conductors on the pole may consist of 120–240-volt power and lighting secondary, and multiple street lighting lamp or pilot wires. All are mounted on racks with conductors spaced vertically eight inches apart on the pole. Telephone joint-use space is provided beneath these conductors.

At the present time, there are five 3,000-kva 13-kv feeders in operation in the city of Spokane, with three more being added this year. Other feeders will be added in the future when and as conditions warrant.

Generator Erection at Coulee Dam; *A. F. Darland (United States Bureau of Reclamation, Coulee Dam, Wash.), J. L. Berry (Westinghouse Electric Corporation, Los Angeles, Calif.).*

The battery of Westinghouse generators now installed at the Grand Coulee power plant are not only the largest hydroelectric generators in existence, but as a group they also have furnished the fault current for the heaviest short circuits ever to have been placed deliberately on any power system anywhere in the world, during recent circuit breaker tests. Reports of these tests previously have been presented before the Institute by other authors.

The Grand Coulee power plant is a hydro plant situated on the Columbia River 93 miles west of the city of Spokane, toward the center of the state of Washington. At this point on the Columbia River the mean annual runoff is 79 million acre-feet; the mean annual flow is 109,000 cubic feet per second; and the 4,300 foot gravity-type concrete dam provides an average net hydraulic head of 330 feet for operation of the turbines. The power plant is located near the electrical center of a vast transmission network extending over the states of Washington, Oregon, Idaho, western Montana, and northern Utah. This network is represented by the Northwest Power Pool, with present total connected resources (peaking) of approximately 3.5-million kw.

Several times during the second world war the power plant at Grand Coulee Dam was the world's greatest power producer, running for weeks at a time with all generators overloaded continuously. Present output is over 24-million kilowatt-hours per day with peak loads exceeding one million kilowatts. In spite of this unprecedented output, nine of the ultimate 18 generators are yet to be installed.

If the present rate of production of approximately 25-million kilowatt-hours per day were valued at 2-mills per kilowatt-hour, this would represent a gross revenue of $50,000 per day or $18,250,000 per year. Or, to make another comparison, if the same energy were to be generated by a modern steam plant, using the usual estimating figure of a pound of coal per kilowatt-hour, it would require 25 million pounds or 312 railroad carloads of coal every 24 hours. This is a carload of coal every $4^1/_2$ minutes.

Since the war, the huge power facilities at Grand Coulee Dam can be turned to the constructive work of peace. Aside from power production for commercial purposes, another function is to supply water for irrigating more than a million acres of potentially irrigable land in the Columbia Basin, where thousands of new settlers may find homes.

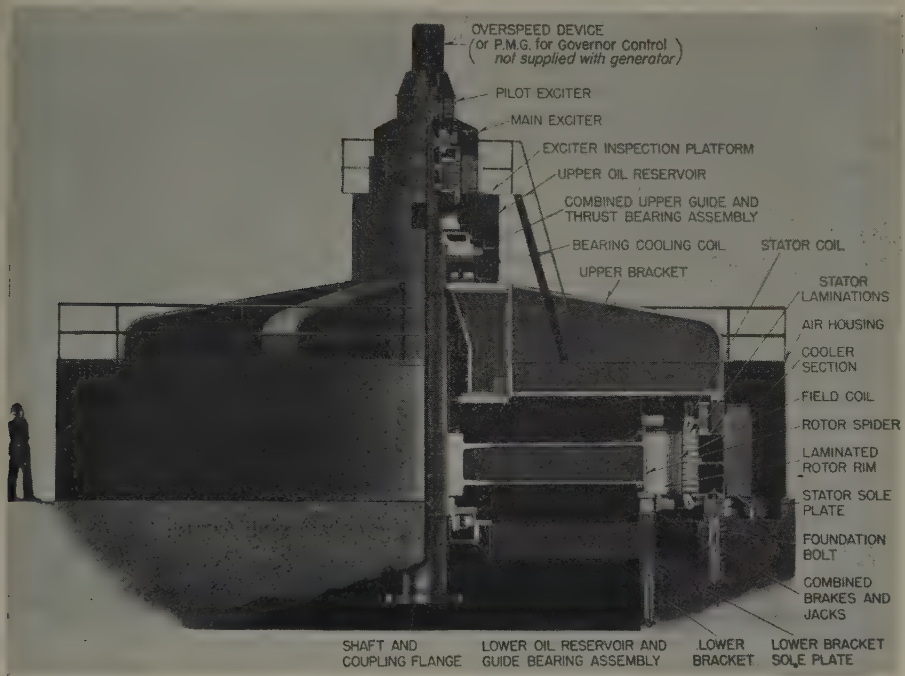


Figure 1. Cross section view of conventional 2-guide bearing generator

Each large generating unit at the Grand Coulee Dam includes a vertical-shaft turbine rated 150,000 horsepower. Water from the reservoir is admitted to a turbine through an 18-foot steel penstock embedded in the dam, entering first the turbine scroll case. This scroll case, 51 feet wide, and weighing 291 tons, was embedded in reinforced concrete while under an internal water pressure of 145 pounds per square inch.

Power is derived from the turbine by the reaction of swiftly flowing water on the 16-foot turbine wheel or runner, a single steel casting weighing about 60 tons. When the turbine carries its rated load, water passes through it at the rate of 141 tons a second, moving at velocities of about 12 miles per hour in the penstock, nearly 20 in the scroll case, and in excess of 50 as it leaves the scroll case through a 34-inch high annular opening, and enters the runner, passing downstream at a velocity of less than five miles per hour.

Connecting a turbine and generator is a shaft 44 inches in diameter, more than 70 feet long, consisting of three sections, and weighing about 200 tons. Its three sections are connected by means of 75-inch flanges, held together by 5.75-inch bolts. Heaviest single generator part is the rotor, a 587-ton mass of steel and copper.

The governors on the 108,000-kva Coulee machines are adjusted to close in 4 seconds from the fully open position when the load is lost, or to open from the closed position in eight seconds upon application of full load.

Figure 1 is a cross section through a conventional 2-guide bearing generator such as those installed at Coulee, with the main and pilot exciter direct-connected to the shaft above the thrust bearing. Note that each bearing has its own oil reservoir and cooling coils and that the upper guide bearing runs in the same oil as the thrust bearing. The only oil piping to the bearings is for filling and draining. In operation there is no oil circulating external to the bearing oil pots.

The actual field erection of a waterwheel generator as large as those installed at Coulee Dam is a major mechanical as well as electrical operation requiring approximately 25,000 man-hours for completion of each machine.

Applications of Induction and Dielectric Heating in Industry; *R. A. Nielsen (Westinghouse Electric Corporation, Los Angeles, Calif.).*

Current flowing in a coil generates eddy currents in any metal object placed within that coil. The depth of penetration of those surface currents can be controlled to a large degree by a choice of frequency; 60 to 2,000,000 cycles have found application for induction heating. In surface hardening applications, the depth of hardened zone obtained is controlled by a choice of frequency, power, and heating time.

There are many uses for induction heating besides hardening; among these are melting, the annealing and heat treating of large and small objects, and the silver brazing of subassemblies. The versatility of the equipment is illustrated by one company's various brazing and hardening applications, all done on the same high-frequency generator.

Frequencies above about two megacycles can be used to heat materials ordinarily classed as electric insulators. The material to be heated is placed between the plates of a capacitor and heat is generated throughout its volume by dielectric losses. As different materials heat at different rates, it is possible to glue wood by taking advantage of the difference in heating rate between wood and glue.

The glue can be polymerized at temperatures above 212 degrees Fahrenheit, while adjoining boards are hardly above 100 degrees Fahrenheit. High-frequency gluing applications are to be found throughout the wood industry from lumber and plywood plants to cabinet maker's shops.

The versatility of dielectric heating is illustrated by the diversified uses to which it has been put. Preforms are heated in the plastics industry; sheets of thermoplastic materials rapidly are sewn or sealed together by heat generated within them by high frequency. Rubber is preheated for molding and curing; sponge rubber is being cured.

There have been a number of applications of dielectric heating for drying; due to the large power required for the evaporation of water, very careful analysis must be made of these applications to insure that they can be justified economically.

The Sections of Our Institute, The Engineer and Continued Education

—*A Message From the President*

I always have said "The Sections are the Institute." It is in the Section that each member resides as he progresses his electrical engineering life, activities, and contributions. Here he associates with his fellow engineers. Here he makes his electrical engineering friendships. And here he extends his friendships to other engineers as opportunity affords for joint meetings with brother engineering and scientific society groups.

The program of the Section should offer the opportunity for each member to make himself a better electrical engineer—a better engineer. The program of the Section should be all-inclusive of all the Section members to broaden them in electrical engineering knowledge and experience, and in engineering and in general experience as they desire. The evaluation program now being studied by our Sections committee gives opportunity for the Section officers to have an appreciation of all possible endeavors. These they should progress.

Our educational programs in the Sections have been outstanding. Many classes have been formed under Section sponsorship appropriate to the member needs. Most of these have been technical. There is opportunity for an extension of these both to technical and to the general.

The engineer cannot feel that his education is completed when he receives his degree. Education in its general sense continues on with him forever if he recognizes the opportunities and applies them to advance his knowledge. In his engineering life experiences become more prominent as he is giving more of his time to practical work where the experiences of life are not written in the book, but which are present to permeate every operation and which are vital and most useful if they are recognized and used. To the use of experience the engineer must apply himself as it is not only the great teacher, but the great source of unfolding knowledge of superlative degree.

The engineer is ever responsible for adding to his store of knowledge and understanding. These additions come from experience, from reading the engineering publications of the engineering societies, from current books, in the trade magazines, in the press, in engineering lectures, and in discussions with his associates. These are of fundamental importance and should receive a definite place in the life of the engineer and he should not neglect to so provide. The Section program can implement these and can create an increasing interest in them to advantage.

And then there is the formal continued education. This may be provided in the company or it may be sought in the colleges in the community where the engineer may be. There is outstanding merit in the engineer taking unto himself some formal continued courses in engineering education for in so doing he will progress this phase of his engineering activity definitely and without diversification. Without the regularly scheduled course the continued education is easy to be neglected. With such, it becomes a part of his engineering life which he progresses to advantage.

When company courses are provided it is relatively easy for the engineer to partake for they are so designed for him. Not that the courses are easy—they are usually hard and difficult. But the opportunity to participate is made appropriate to the engineering work and to advantage. Engineering knowledge moves along with the continued engineering contributions which engineers ever are bringing newly into existence. It stands to reason, therefore, that there must be continued study by the engineer to participate in the knowledge of these advances.

Some engineers may choose to continue in formal college courses along with their engineering work. This has the advantage of continuing with the college atmosphere which is good, and the work leads to a degree which is valuable and is a mark of distinction.

But there are many engineers who do not have opportunity for the formal courses who could progress one or more subjects and to great advantage. These are available in the college curricula. Here is an opportunity for the Section program to be further co-ordinated to direct this activity towards the engineering schools in the vicinity. This is being done in the technical—I urge its extension to the general.

Especially is this important and of the greatest significance in the pursuit of the more general subjects to which the engineer should give comprehensive and careful thought. Usually these subjects are not given in company courses, but they are given in the colleges and the engineer should progress them. These are such as economics, logic, psychology, history, English, languages, government, and the like. Courses in personnel relations are becoming more and more prominent. Engineers in general are criticized that they do not have good fundamental knowledge of these subjects, and engineering education sometimes is criticized that these subjects are not included to great enough degree in the engineering curriculum. The elements of these are included in the usual engineering courses.

Everett S. Lee

But there is the further thought that the usefulness of these more general subjects increases to the engineer as he lives on in his engineering life; thus they well can come later in their progression beyond the elements. But come they should and the engineer who makes a place for them in his engineering life in a nearby college will find great advantage accruing to himself—and the college faculties will be privileged to have practicing engineers within their classes to bring to them the engineering viewpoint as the engineer receives the experience in these subjects from living with the professors. The more definite progression of these classes will be for great good for the engineer who arranges that he participates, and will serve the engineering and teaching professions to outstanding advantage. The continued activity of the Sections of our Institute to arrange to make these classes available to their members is an outstanding service of great importance.

For Section officers and committee chairmen eager to progress this work there is material available at Institute headquarters—particularly the booklet, "Section Activities," prepared by the Sections committee under past Chairman G. W. Bower is most helpful.

I bring these thoughts to our members that they consider them and to our Section officers that they progress them. The continued education of our members will be their greatest strength.

Electronic Instrumentation to Be Conference Subject

Program plans are substantially complete for a joint AIEE-Institute of Radio Engineers conference on electronic instrumentation in nucleonics and medicine to be held November 29–December 1, 1948, in the main auditorium of the Engineering Societies Building, at 33 West 39th Street, New York, N. Y. Because of the wide range of subject matter covered in the conference and the probable changes in conferees from day to day, no plans have been made at the present time for social activities.

Hotel rooms are still difficult to obtain in New York, so reservations should be made as early as possible by contacting the desired hotel directly. The planning committee is making no arrangements for obtaining hotel reservations.

Registration fees for the conference are as follows: $4 at the conference or $3 for those who register in advance. Registration at the conference will take place in the main lobby of the Engineering Societies Building. Program on following page.

Future AIEE Meetings

Southern District Meeting
Birmingham, Ala.
November 3–5, 1948
(*Final date for submitting papers—closed*)

AIEE/IRE Conference on Electronic Instrumentation in Medicine and Nucleonics
Engineering Societies Building
New York, N. Y.
November 29–December 1, 1948

AIEE Conference on the Textile Industry
Atlanta, Ga.
Fall, 1948

AIEE Conference on Electric Welding
Engineering Society of Detroit Building
Detroit, Mich.
December 6–8, 1948

AIEE Conference on High-Frequency Measurements
Washington, D. C.
January 10–12, 1949

Winter General Meeting
Pennsylvania Hotel, New York, N. Y.
January 31–February 4, 1949
(*Final date for submitting papers—November 16*)

AIEE Conference on the Textile Industry
Boston, Mass.
May 4, 1949

AIEE Conference on Electron Tubes
March, 1949

AIEE Conference on the Rubber and Plastics Industry
Akron, Ohio
March, 1949

South West District Meeting
Dallas, Tex.
April 19–21, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949

Midwest General Meeting
Cincinnati, Ohio
October 17–21, 1949

29 Technical Sessions Planned for Winter Meeting

In accordance with previous announcements, the AIEE 1949 winter general meeting is scheduled to be held in New York, N. Y., during the week of January 31 through February 4, 1949. A new departure in Institute practice will occur for this meeting in that the meeting headquarters will be at the Pennsylvania Hotel. This change from the Engineering Societies Building has been made to provide more adequate meeting space and permit effective staging of the extensive program now in course of development. To be able to obtain rooms at the headquarters hotel also should prove a great time saver.

The tentative technical program calls for 29 technical sessions and six conferences for the presentation and discussion of the following subjects: Applied mathematics; progress in fluorescent lighting; d-c machinery; education; symposium on control and protection of household equipment; communication; selenium rectifiers; symposium on gas turbine development; power generation; protection of electronic power converters; education and power electronics; instruments and measurements; transmission line protection; chemical, electrochemical, and electrothermal; system engineering; land transportation; analog computers; industrial control; symposium on rate of rise and the recovery voltages on distribution systems; symposium on primary supplies to distribution systems; transmission and distribution; carrier current; insulated conductors, servomechanisms; electric welding.

The highlights of the evening entertainment programs will be the dinner-dance, at the Pennsylvania Hotel on Tuesday, February 1, and the smoker at the Commodore Hotel on Thursday, February 3. Particular attention is called to the fact that to provide suitable accommodations for both affairs it has been necessary to reverse the nights on which these affairs have been staged in the past. The prices for tickets have not been announced as yet. An extensive program for the entertainment of the women attending will be developed under the direction of a ladies' entertainment committee.

In accordance with the practice followed during the last few years, but particularly for the convenience of members from out-of-town, blocks of theater tickets for popular shows will be available for sale in advance of the meeting. Tickets for broadcasts also will be provided.

The inspection trips committee is arranging for a series of interesting trips as close by correlated as possible with the technical program. Under consideration at the present time are the following: The RCA Laboratories at Princeton; Navy Yard Laboratory; Pfizer penicillium factory; cable plant; DuMont television laboratories; Ford assembly plant; Sewarren generating station, and the steamship *America*. This program is still in the tentative stage.

To help defray part of the expenses incurred by the Institute in the holding of meetings, the board of directors has ruled that registration fees will be charged for both members and nonmembers. For members the fee will be $3; for nonmembers $5. As it is believed most of those who attend the meeting will want to be located in the headquarters hotel, the Pennsylvania has agreed to set aside a large number of rooms for Institute use. Registration forms for room reservations will be prepared and the membership is urged to take advantage of this opportunity and to enter reservations as soon as possible after the necessary forms become available.

Further and more definite information on what promises to be one of the largest AIEE meetings ever held will appear in *ELECTRICAL ENGINEERING* as it becomes available. The greater facilities available at the hotel over those at the Engineering Societies Building will insure a more effective meeting from every viewpoint.

AIEE PROCEEDINGS

Order forms for current AIEE *PROCEEDINGS* have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of AIEE *PROCEEDINGS* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *TRANSACTIONS*.

AIEE *PROCEEDINGS* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*). They are available to AIEE Student Members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *PROCEEDINGS* will appear in *ELECTRICAL ENGINEERING* in abbreviated form.

Location of Order Forms	Meetings Covered
Apr '48, p 49A	Winter general
Aug '48, p 45A	Great Lakes District North Eastern District Summer general
Oct '48, p 43A	Pacific general Middle Eastern District

Tentative Program

AIEE/IRE Conference on Electronic Instrumentation in Nucleonics and Medicine

Monday, November 29

Presiding: Doctor W. A. Geohegan, Cornell University Medical College, New York, N. Y.

9:00 a.m. Registration—Main Lobby

10:00 a.m. Morning Session

Biological Requirements in Amplifiers. *Doctor Harry Grundfest*, College of Physicians and Surgeons, Columbia University, New York, N. Y.

Present Practice in Biological Amplifier Design. *John P. Hervey*, Johnson Foundation, University of Pennsylvania, Philadelphia, Pa.

Instrument Requirements in Audiology. *Doctor Aram Glorig*, Walter Reed Hospital, Washington, D. C.

2:00 p.m. Afternoon Session

Biological Requirements in Recording Devices:

- **Cathode-Ray Photography.** *Doctor Charles M. Berry*, Cornell University Medical College, New York, N. Y.
- **Electrocardiograph.** *Doctor John L. Nickerson*, College of Physicians and Surgeons, Columbia University, New York, N. Y.
- **Electroencephalograph.** *Doctor Charles H. Richards*, Cornell University Medical College, New York, N. Y.
- **Miscellaneous Recorders.** *Doctor John R. Pappenheimer*, Harvard Medical School, Harvard University, Cambridge, Mass.

Engineering Aspects of Biological Recorder Design. *S. R. Gilford*, National Bureau of Standards, Washington, D. C.

Tuesday, November 30

Presiding: Doctor G. W. Dunlap, General Electric Company, Schenectady, N. Y.

10:00 a.m. Morning Session

Introduction to Nucleonics Instrumentation. *A. Dahl*, Instrument Branch, United States Atomic Energy Commission, Oak Ridge, Tenn.

Biological Requirements for Radioactive Isotope Measurements. *Doctor C. A. Tobias, Jr.*, Donner Laboratory of Medical Physics, University of California, Berkeley, Calif. Discussion by *Doctor L. Marinelli*, Argonne National Laboratory, Chicago, Ill.

Geiger Counters. *Doctor H. Friedman*, Naval Research Laboratory, Washington, D. C.

Thin Window Beta Counters. *Doctor F. C. Henriques, Jr.*, Tracer Laboratories, Inc., Boston, Mass.

2:00 p.m. Afternoon Session

Autoradiographic Technique. *George A. Boyd*, School of Medicine and Dentistry, The University of Rochester, Rochester, N. Y.

Stable Isotope Measurement. *Doctor David Rittenberg* College of Physicians and Surgeons, Columbia University, New York, N. Y.

Biological Effects of Radiation and Health Protection. *Doctor G. Failla*, College of Physicians and Surgeons, Columbia University, New York, N. Y.

Health Protection Instrumentation. *Doctor F. R. Shonka*, Argonne National Laboratory, Chicago, Ill.

Wednesday, December 1

Presiding: H. H. Goldsmith, Brookhaven National Laboratory, Upton, Long Island, N. Y.

10:00 a.m. Morning Session

Proportional Counters. *Doctor S. A. Korff*, New York University, New York, N. Y.

Neutron Detection. *Doctor H. L. Anderson*, Institute for Nuclear Studies, University of Chicago, Chicago, Ill.

Ionization Chambers. *J. A. Victoreen*, Victoreen Instrument Company, Cleveland, Ohio

Ionization Chamber Measurements. *E. W. Molloy*, National Technical Laboratories, South Pasadena, Calif.

Stabilized High-Voltage Supply for Counters and Chambers. *Doctor W. A. Higinbotham*, Brookhaven National Laboratory, Upton, Long Island, N. Y.

2:00 p. m. Afternoon Session

Electron Multiplier Counters. *Commander P. S. Johnson*, Bureau of Ships, Navy Department, Washington, D. C.

Crystal Counters. *Doctor Robert Hofstadter*, Palmer Physical Laboratory, Princeton University, Princeton, N. J.

Electronic Counting Techniques. *Doctor Matthew Sands*, Massachusetts Institute of Technology, Cambridge, Mass.

Photographic Emulsions for Use in Radiation Measurements. *Doctor J. Spence*, Research Laboratories, Eastman Kodak Company, Rochester, N. Y.

President Lee Addresses New International Section

AIEE President Everett S. Lee addressed the newly formed Niagara Falls Section at the inaugural meeting on September 9, 1948. In his message, he praised the membership for combining the American and Canadian Subsections to form an international Section, the 83d of the Institute. "The real strength of the Institute is based upon the engineering friendships brought about by such actions," he said, and then added, "The Institute is the Sections."

Catching the enthusiasm of the members, President Lee gave his opinions as to how individual engineers can gain greater recognition, and how the Institute is working to help them. He spoke of the need for working engineers to continue training and the necessity for those in the field to pass on their experience to schools and student engineers.

President Lee was introduced to the membership by one of his former classmates at the University of Illinois, and also a former coworker at the General Electric Company, G. D. Bagley. Also present at the meeting were: J. C. Strasbourger, chairman of the Sections committee; R. T. Henry, a director of the Institute; D. G. Geiger, vice-president of District 10; D. C. Churchill, past-chairman of the Toronto Section; J. T. Sowars, chairman of the Niagara Frontier Section; and H. C. Lindberg, past-chairman of the Niagara Frontier Section.

The new officers for the international Section will be: W. Lore Eliason, *chairman;* William G. Barr, *vice-chairman;* John A. Persson, *secretary-treasurer;* Eldridge A. Dillon, *assistant secretary-treasurer*.

Among those present at the dinner meeting held during AIEE President Lee's visit to the new Niagara Falls Section were, seated left to right, J. T. Sowers, D. G. Eiger, President E. S. Lee, W. L. Eliason, R. T. Henry, and J. C. Strasbourger

Registration Fees Established for District and General Meetings

As part of the effort to balance Institute finances and place as many activities as possible on a self-supporting basis, the board of directors has established a schedule of registration fees for future District and general meetings.

The schedule of charges to be applied starting with the 1948 Midwest general meeting in Milwaukee, Wis., October 18–22, 1948, is as follows:

General meetings:	
Members	$3
Nonmembers	$5
District meetings:	
Members	$2
Nonmembers	$3

Families of members and Students will be admitted without charge.

Funds from both member and nonmember fees are to be remitted to Institute headquarters and it is the responsibility of the local committee to collect the fees as a part of the general duty of conducting the sessions.

The resolution, adopted at the board of directors meeting of August 5, 1948, supersedes the previous schedule which would have required an average member registration of about $7 at meetings held during the past year. The directors considered this excessive.

Program Announced for December Welding Conference

Announcement of a tentative program reveals that the conference on electric welding to be held in Detroit, Mich., December 6–8, 1948, will cover many timely arc and resistance welding problems. An inspection trip at Ford Motor Company's River Rouge plant further highlights the comprehensive 3-day program.

Registration is now in process under the direction of L. E. Donelson of the Michigan Bell Telephone Company, Detroit, Mich. The conference is sponsored by the AIEE committee on electric welding in co-operation with the AIEE Michigan section, the Detroit section of the American Welding Society, and the Industrial Electrical Engineers' Society of Detroit.

Hotel accommodations will be available at the Detroit Leland for those who register early. Reservations should be made by contacting the hotel direct and referring to the conference. Meetings will take place in the Rackham Memorial Building of the Engineering Society of Detroit. (Program below).

Illinois AIEE Wives Begin Fall Program

Members of the AIEE Wives of the Illinois Valley Section have begun their program for the year. Holding their meetings on the same evening as their husbands, the purpose of this group, formed in September 1947, is to gather for the enjoyment of social evenings and to hear speakers of interest.

The original group had 50 members when first organized, but now has grown to almost 80 women. Officers are: Mrs. Walter J. Johnson, wife of the chairman of the Illinois Valley Section, as president; Mrs. Ernest Stone, as vice-president; Mrs. Lee Ranney, as secretary; Mrs. T. F. Buehrig, as treasurer.

The committee chairmen are Mrs. G. E. Walters, Mrs. Roland Pfeiffer, and Mrs. William Sedgwick.

Tentative Program

Conference on Electric Welding, Detroit, Mich., December 6-8, 1948

Monday, December 6

8:30 a.m. Registration

9:30 a.m. Opening Meeting

Welcome: J. R. North, director AIEE, Commonwealth and Southern Corporation, Jackson, Mich.

Opening of Conference: E. H. Vedder, chairman, National Committee on Electric Welding, Westinghouse Electric Corporation, Buffalo, N. Y.

9:30 a.m. Fundamentals of Arc Welding

Chairman: R. C. McMaster, Battelle Memorial Institute, Columbus, Ohio

The Nature of the Arc. *Doctor J. D. Cobine*, General Electric Company, Schenectady, N. Y.

New Observations on Welding Arcs. *Doctor Lauriston P. Wilson*, Renssalaer Polytechnic Institute, Troy, N. Y.

Electrode Burn-off in the Welding Arc. *D. C. Martin, P. J. Rieppel, C. B. Voldrich*, Battelle Memorial Institute, Columbus, Ohio

Arc Welding Equipment. *R. C. Freeman*, General Electric Company, Fitchburg, Mass.

2:00 p.m. Inert Atmosphere Arc Welding

Chairman: E. F. Steinert, Westinghouse Electric Corporation, Buffalo, N. Y.

Introduction to Inert Atmosphere Arc Welding. *H. T. Herbst*, The Linde Air Products Company, Newark, N. J.

Some Problems in Argon Arc Welding of Thick Aluminum Plate. *R. D. Williams, P. L. Mirolo, C. B. Voldrich*, Battelle Memorial Institute, Columbus, Ohio

Inert Atmosphere Welding of Aluminum. *G. O. Hoglund*, Aluminum Company of America, New Kensington, Pa.

Equipment and Techniques in Gas-Shielded Arc Welding. *E. H. Roper*, Air Reduction Sales Company, Murray Hill, N. J.

Equipment for Inert Arc Welding. *A. U. Welch*, General Electric Company, Holyoke, Mass.

Radio Interference Problems in Welding. *C. W. Frick*, General Electric Company, Schenectady, N. Y.

Tuesday, December 7

9:00 a.m. Resistance Welding—Round Table Discussion on 3-Phase Welding

Chairman: C. E. Smith, The Taylor Winfield Corporation, Warren, Ohio

Discussion Leader: *Doctor J. D. Leitch*, Electric Controller and Manufacturing Company, Cleveland, Ohio

Recent Advances in Single-Phase Welding. *I. W. Johnson*, General Electric Company, Schenectady, N. Y.

Three-Phase Welding, Frequency Converters:
First paper—*F. L. Brandt*, Thomson Electric Welder Company, Lynn, Mass.
Second paper—*J. F. Deffenbaugh*, Federal Machine and Welder Company, Warren, Ohio
Third paper—*J. L. Solomon*, Sciaky Brothers, Chicago, Ill.

Three-Phase Welders, Metallic Rectifiers. *R. H. Blair*, Taylor Winfield Corporation, Warren, Ohio

1:20 p.m. Inspection Trip

The Ford Motor Company

7:30 p.m. Maintenance of Resistance Welding Equipment

Chairman: G. M. Chute, General Electric Company, Detroit, Mich.

Installation for Low Maintenance. *J. W. Quinn*, Delco Products Division, General Motors Corporation, Dayton, Ohio

Preventive and Corrective Maintenance of Welding Equipment:

First paper—*C. H. Davis, Jr.*, The Budd Company, Philadelphia, Pa.

Second paper—*J. B. Welsch*, Cutler-Hammer Inc., Milwaukee, Wis.

Use of Instruments in Maintenance. *Ralph Pelton*, Precision Welder and Machine Company, Cincinnati, Ohio

Training Men to Maintain Welders and Controls:
First paper—*B. J. Gelmine*, Ford Motor Company, Detroit, Mich.
Second paper—*L. M. Skidmore*, General Motors Institute, Flint, Mich.

Wednesday, December 8

9:00 a.m. Resistance Welding—Plant Distribution Systems

Chairman: C. M. Rhoades, Jr., General Electric Company, Schenectady, N. Y.

Nature of Resistance Welding Loads. *C. B. Stadum*, Westinghouse Electric Corporation, Buffalo, N. Y.

Effect of Electrical Variations on Welding. *R. S. Phair*, The Budd Company, Philadelphia, Pa.

User Power Supply Problems. *T. Morgan*, Buick Motor Division, General Motors Corporation, Flint, Mich.

Dummy Loads Applied to Large Industrial Welders to Reduce Voltage Fluctuations. *A. W. Brown, S. E. Johnson*, Illinois Northern Utilities Company, Dixon, Ill.

Economic Aspects of Distribution Systems. *W. K. Boice*, General Electric Company, Schenectady, N. Y.

2:00 p.m. Providing Power for Resistance Welding Loads

Chairman: C. N. Clark, Duquesne Light Company, Pittsburgh, Pa.

Present and Future Use of Resistance Welding. *J. H. Cooper*, The Taylor Winfield Corporation, Warren, Ohio

Utility Problems in Supplying Power. *H. B. Wood*, Duquesne Light Company, Pittsburgh, Pa.

Welding Calculations—Effect of Conductor Configuration in Overhead Lines. *H. W. Tietze*, Public Service Electric and Gas Company, Newark, N. J.

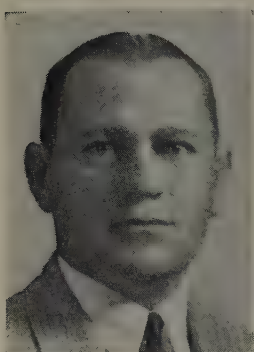
Economical Service for Resistance Welders. *E. F. Dissmeyer*, Commonwealth and Southern Corporation, Jackson Mich.

Introducing AIEE Section

Some of the men who will preside over AIEE Sections during 1948–49;

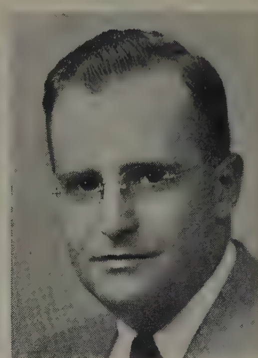
R. E. Stroppel
(*Cincinnati Section*)

C. K. Bishop
(*Columbus Section*)



C. W. Keller
(*Denver Section*)

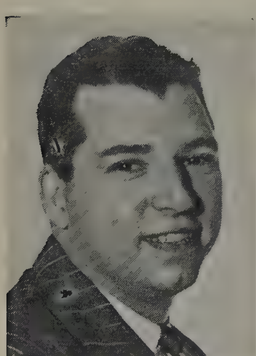
R. S. Davis
(*Florida Section*)



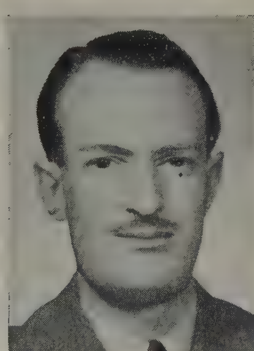
J. V. Gebuhr
(*Iowa Section*)

P. D. Ankrum
(*Ithaca Section*)

J. E. Treweek
(*Lehigh Valley Section*)



C. W. Freeman
(*Mansfield Section*)

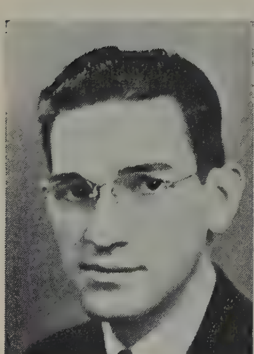


M. M. De Lascurain
(*Mexico Section*)

Sidney McArthur
(*Montana Section*)

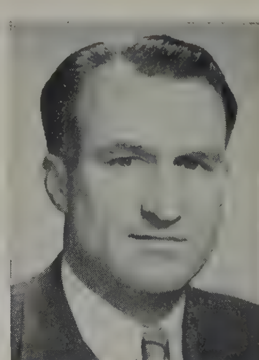
M. C. Thurling
(*Montreal Section*)

A. A. Little
(*Nebraska Section*)



M. G. Zervigon
(*New Orleans Section*)

W. L. Eliason
(*Niagara Falls Section*)



O. A. Gustafson
(*San Francisco Section*)

H. L. Palmer
(*Schenectady Section*)

H. R. Brown
(*Seattle Section*)

Chairmen for 1948-49

others appeared in the October issue

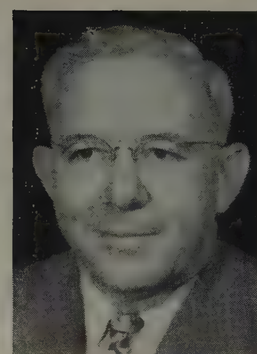
R. O. Williams
(Shreveport Section)

E. W. Tipton
(Sharon Section)

R. M. Koontz
(South Bend Section)

M. G. Toole
(South Carolina Section)

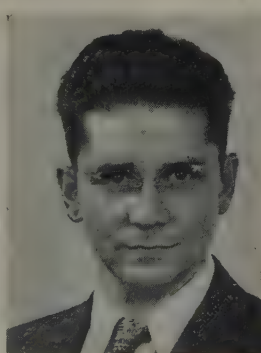
M. F. Noster
(South Texas Section)



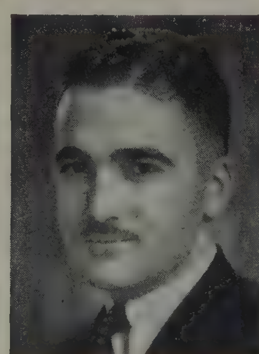
O. W. Hurd
(Spokane Section)

J. L. Hyland
(Springfield Section)

L. M. Moore
(Syracuse Section)



M. W. Keck
(Toledo Section)

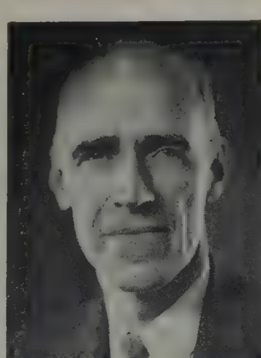


J. F. Moore
(Toronto Section)

A. D. Bailey
(Urbana Section)

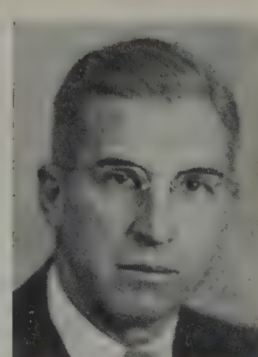
Thomas Jordan
(Utah Section)

W. T. Johns
(Virginia Section)

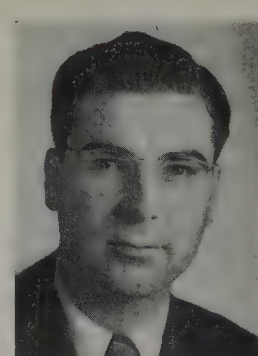


R. D. Bennett
(Washington Section)

T. R. Cooper
(West Virginia Section)



E. D. Manspeaker
(Wichita Section)



D. L. Watkins
(Worcester Section)

Geophysics Symposia Planned for Electronic Engineers

A series of technical symposia of interest to the electronic engineers in geophysics is being planned for presentation in Houston, Tex., during the coming winter months. Now in preparation, the first of these meetings will be a round-table discussion of automatic volume control amplifiers for geophysical applications. The date of the first meeting is scheduled tentatively for Monday, November 22, 1948. Topics for later meetings will be selected to meet the needs and wishes of the group.

The technical symposia are being conducted as a joint project of the AIEE, The Society of Exploration Geophysicists, and The Institute of Radio Engineers. The primary purpose of the meetings is to bring together for group study and discussions the electronic specialists scattered throughout various geophysical laboratories of the petroleum industry. It is hoped that a program of this kind will operate not only for the technical development of the individuals but that it will stimulate the writing and publication of technical papers, the development of standards, and a wider exchange of technical knowledge and methods. Following a trial period in Houston, it is planned to initiate similar meetings in other cities geophysical laboratories.

Details regarding the technical symposia will be announced hereafter through the local sections of the sponsoring societies in Houston. Further details or notices of the meetings may be secured by writing either William M. Rust, Jr., of The Humble Oil and Refining Company, Houston, or Laurence G. Cowles of The Superior Oil Company, Pellaire, Tex.

Electronics Committee Plans Winter Meeting Conference

If sufficient suitable material is available, the AIEE electronics committee plans to repeat during the 1949 winter general meeting similar successful conferences of past years.

The committee desires to schedule presentations on new electron tubes or new electronic devices and applications that have been announced but of which no technical descriptions have been made available. Advance preparation of a technical paper is not necessary; a title and abstract are sufficient for consideration on the program.

Members of the Institute knowing of suitable items for this program are asked to send their suggestions to R. S. Gardner at Institute headquarters, 33 West 39th Street, New York 18, N. Y., by November 16, 1948.

PERSONAL NOTES.......

Charles S. Rich (A '30), formerly secretary of the AIEE technical program committee, Institute headquarters, New York, N. Y., has been named editor of the Institute's official publications, *ELECTRICAL ENGINEERING* and *TRANSACTIONS*, to succeed G. Ross Henninger who recently resigned (*EE, Oct '48 p 1014*). Mr. Rich was born in Mount Vernon, N. Y., on February 19, 1900. Following graduation as a mechanical engineer from Cornell University in 1926 he was appointed engineer-in-charge of the underground systems bureau of the Westchester Lighting Company, Mount Vernon, N. Y. He remained with that company until 1928, when he became district engineer for the southern district of the United States Leather Companp, Ridgway, Pa. Rich joined the AIEE staff in February 1930 in his recent capacity as secretary to both the technical program committee and the committee on the award of Institute prizes. In the former position he has been responsible for the administrative details involved in the handling of several hundred technical papers each year. Rich is also well known to AIEE members through his work in the preparation of technical programs for AIEE meetings and in the processing of manuscripts for review.

Ward Harrison (F '36), director of engineering for General Electric's lamp department at Nela Park, Cleveland, Ohio, resigned on September 1, 1948, under that company's pension plan. He is 60 years old, and had been with the lamp department for 39 years. A native of East Orange, N. J., Harrison graduated in 1909 from Stevens Institute of Technology, Hoboken, N. J., as a mechanical engineer. The honorary degree of doctor of illuminating engineering was conferred upon him by the Case Institute of Technology, Cleveland, Ohio, in 1940. Harrison joined the General Electric lamp department ln 1909, and the method of lighting calculation he helped develop in 1919 while working there is almost universally employed today. Among his many contributions to lighting practices are the "RLM standard reflector," the "glassteel diffuser," the first clear-top semi-indirect unit, and the first street lanterns incorporating prismatic refractors. He also pioneered with the first continuous-row fluorescent installation in the industrial field and has been working on the elimination of glare in industrial lighting. He is the author of several books on lighting and numerous technical papers and articles. A fellow and former president of the Illuminating Engineers Society, Harrison also holds membership on three international illuminating societies: the United States National Committee of the International Commission on Illumination, the Association Française des Eclairagistes, and the British Illuminating Engineering Society. A member of Tau Beta Pi and Sigma Xi fraternities, Doctor Harrison also has been vice-president of the Ohio Good Roads Federation and the Cleveland, Ohio, Engineering Society.

W. R. MacDonald, Jr. (A '33, M '44), associate editor of *ELECTRICAL ENGINEERING*, has resigned as of September 30, 1948. He joined the AIEE editorial staff in 1934 and was named an assistant editor in 1938. Following service as a major with the Signal Corps, United States Army, from 1941 to 1944, MacDonald returned to AIEE publications as acting editor, until the return of G. Ross Henninger in December, 1945. Since then, he has acted in the capacity of associate editor. MacDonald was born August 22, 1910, in New York N. Y., and received the degree of electrical engineer from Cornell University in 1932. After his graduation, and until he joined the AIEE editorial staff, he established and operated a radio service and repair business. Mr. MacDonald was originally employed by AIEE during a major period of change in editorial policy and while the AIEE 50th Anniversary issue of *ELECTRICAL ENGINEERING* was in preparation. Since that time, he has made a considerable number of contributions to the maintenance and development of the Institute's publications services. He is a member of Eta Kappa Nu fraternity and a Fellow of the Radio Club of America.

E. T. B. Gross (A '34, M '40), professor of electrical engineering, Illinois Institute of Technology, Chicago, has been elected chairman of project 3 (bibliography of literature on grounding devices) of the fault limiting devices subcommittee on the AIEE protective devices committee for 1948–49, and has also been appointed chairman of subcommittees 1 (project committee on bibliography of relay literature) and 5 (project committee on sensitive ground protection) of the AIEE relay committee for 1948–49.

Ralph Bown (A '30, M '41), director of research, Bell Telephone Laboratories, Inc., New York, N. Y., is the recipient of the Institute of Radio Engineers' Medal of Honor. This award is given in recognition of distinguished service rendered through substantial and important advancement in the science and art of radio communication. Doctor Bown's work was concerned with various aspects of radio broadcasting and ship-to-shore and overseas telephony. A

Ralph Bown

native of Fairport, N. Y., Bown graduated from Cornell University in 1913, and went on to obtain both his master's degree and the degree of doctor of philosophy. After service in the Signal Corps in World War I, Bown joined the development and research department of the American Telephone and Telegraph Company, and was named associate director of radio research when that department became the Bell Telephone Laboratories in 1934. He was named director of radio research in 1936, and director of television research in 1938. In 1944, Bown became assistant director of research, and then was named director of research in June 1946. Doctor Bown holds fellowships in the American Academy for the Advancement of Science and the Institute of Radio Engineers, of which he was president in 1926. He is a member of the following scientific fraternities and societies: Sigma Xi, Eta Kappa Nu, Gamma Alpha, and the Acoustical Society of America. He has authored several technical papers and holds numerous patents relating to radio and telephone communication.

G. R. Milne (A '21, M '36) has been appointed mechanical engineer for the Consolidated Edison System, New York, N. Y., as one of a number of recent organization changes within that company. Other promotions include: **J. E. Goodale** (A '21., F '34) as manager of the system operation department; **J. E. McCormack** (A '27., F '44) to the new post of staff engineer department office; **W. B. Fisk, Jr.** (A '28, M '34) as outside plant engineer; **T. E. Duncan** (A '30) as assistant outside plant engineer. McCormack is a former chairman of the AIEE system engineering committee.

L. W. Chubb (A '09, F '21) director emeritus of the Westinghouse Research Laboratories has retired after 43 years with the Westinghouse Corporation. He joined that company in 1905, immediately after graduating from Ohio State University. In 1916 Chubb helped found the laboratories he later headed, and in 1920, he was named head of all Westinghouse radio engineering activity. He became director of the laboratories in 1930, and assumed his honorary emeritus in March 1948. During World War II, Chubb was active in the development of jet propulsion, microwave apparatus, torpedoes, and high-temperature alloys. He holds more than 150 patents covering inventions in radio, electronics, jet propulsion, telephony, electric equipment, and related fields. A member of the AIEE board of examiners from 1940 to 1943 Doctor Chubb has been a member of the following AIEE Committees: editing, 1918–20; electrophysics, 1914–16, 1918–24; telephony and telegraphy, 1921–24; communications, 1924, 1927–29, 1934–42; research, 1930–42 (chairman 1930–32); award of Institute prizes, 1930–32; electrochemistry and electrometallurgy, 1931–36; Edison Medal, 1933–35; code of principles of professional conduct, 1933–38; Lamme Medal, 1935–38; Institute policy, 1940–42; Engineering Foundation board, 1944–48; chairman, nucleonics, 1946–48. In 1947, Chubb was awarded the John Fritz Medal, the nations highest tribute to scientists and engineers.

R. M. Mock (A '44), former executive vice-president of Lear, Inc., Grand Rapids, Mich., has been named president of that company. He has been carrying the duties of that office for several months during the expansion of the company. Mock joined Lear, Inc., in 1940, and held the positions of application engineer, chief engineer, sales manager, and manager of the electromechanical division, prior to being vice-president.

J. M. Stuart (M '47), vice-president of the Dayton (Ohio) Power and Light Company, has been elected a director of that company. He has also been appointed associate general manager. Stuart will now be in charge of all electric operations and several other divisions of the firm. He has advanced in the company from assistant supervisor of the underground department in 1930, through manager of the electric division (1942) and manager of electric operations (1947) to his new offices.

H. T. Killingsworth (A '23, M '30), former area plant manager for the southern area of the American Telephone and Telegraph Company, is now the general manager of the long lines department of that company.

D. M. Manson (A '40), formerly with Electronics Devices Co., Ltd., of Canada, has been appointed as technical assistant in charge of electrical standardization for the Canadian Standards Association. A graduate of the University of Toronto, Manson has been working in the field of electricity for the past nine years.

C. A. Clancy (M '47), assistant general superintendent, Niagara Falls Power Company, Niagara Falls, N. Y., has been appointed general manager of that company's subsidiary, Canadian Niagara Power Company, Ltd. Clancy joined the company in 1924 in the operating department, and advanced through the positions of chief operator, and assistant operating superintendent to his present post.

J. P. Maxfield (M '23, F '27), formerly of the Bell Telephone Laboratories, New York, N. Y., has accepted appointment as superintending scientist of the United States Navy Electronics Laboratory, San Diego, Calif. He will be in charge of all scientific and technical research conducted at the laboratory in the fields of radio, radar, and sonar. An inventor of long standing, Maxfield was director of the National Defense Research Committee's division of Physical Research during World War II. He is the author of numerous papers and articles on acoustics, electrochemistry, and physics. Among his inventions are numerous devices used in telephony, radio broadcasting, electrical recording, and film sound reproduction. Maxfield is a Fellow of the American Physical Society, and a member of both the Acoustic Society of America and the Society of Motion Picture Engineers.

H. E. Young (A '22), vice-president in charge of sales, Northern States Power Company, Minneapolis, Minn., has retired after 36 years of service. His past experience includes a world-wide study of electric rates made for the Philippine government, and several years with the Minneapolis General Electric Company as their sales manager.

T. F. Peterson (A '25, M '32), former manager, electric sales division, American Steel and Wire Company, Cleveland, Ohio, has been named to head a new division of that company which will direct sales of electrical wire and cable products.

G. M. Keenan (A '20, F '36), former chief engineer, Pennsylvania Power and Light Company, Allentown, Pa., has been elevated to the position of vice-president. He served on the AIEE membership committee from 1927 to 1929, and on the AIEE communications committee from 1931 to 1936.

C. P. Cooper (A '08, M '21) has retired as vice-chairman of the board of the American Telephone and Telegraph Company, New York, N. Y., after 40 years of service. From 1926 on, he had been vice-president in charge of finance, and became executive vice-president in 1946. He began work with the New York Telephone Company as a junior engineer, and rose through the ranks to become president of the Ohio Bell Telephone Company in 1923. He will continue as a member of the board of directors.

H. A. Chinn (M '45), chief audio-video engineer of the Columbia Broadcasting system, has been awarded the Presidential Certificate of Merit "for outstanding fidelity and meritorious conduct in aid of the war effort—in World War II." Chinn was consultant to the national defense research committee division on radio and radar countermeasures. He is a fellow of the Institute of Radio Engineers, and has been associated with the Columbia Broadcasting System since 1932.

C. S. Rich

Ward Harrison

L. W. Chubb

J. T. Wilson of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been appointed chairman of the subcommittee on studies of nuclear theory of the AIEE nucleonics committee for 1948–49.

W. E. Barbour (M '48), president of Tracerlab, Inc., Boston, Mass., has been appointed chairman of the subcommittee on isotopic tracers of the AIEE nucleonics committee for 1948–49.

F. C. Rushing (M '45), manager, motor engineering department, Westinghouse Electric Corporation, Buffalo, N. Y., has been appointed chairman of the induction machinery subcommittee of the AIEE rotating machinery committee for 1948–49.

M. W. Keck (A '38, M '47) of the Toledo (Ohio) Edison Company has been appointed assistant superintendent of system operation. A graduate of the University of Toledo, and a member of the Toledo Edison Company's engineering staff since 1937, Mr. Keck has been conducting a study of relaying problems and system analysis for the last three years. He is a member of the AIEE carrier current committee for 1947–48.

H. H. Plank (A '41), former vice-president and assistant general manager of the Delaware Power and Light Company, Wilmington, Del., has been named vice-president in charge of engineering and operations.

Robert E. Pierce (A '21, F '47) has been appointed consulting electrical engineer for Ebasco Services, Inc., New York, N. Y. He has been with that company since 1927. Mr. Pierce was a member of the AIEE protective devices committee from 1943 to 1946.

W. L. Thrailkill (M '42) of the Washington Water Power Company, Spokane, was elected president of the Northwest Electric Light and Power Association at the Association's 41st annual meeting, July 15, 1948.

A. E. Rotta (A '42), formerly with the Bonneville Power Administration, Vancouver, Wash., will be the new chief engineer for the Clark County Public Utility Department at Vancouver.

E. A. Loew (A '08, F '36), dean of engineering of the University of Washington, Seattle, has retired. He will continue on the faculty as a professor of electrical engineering.

H. A. Cornelius (A '27, M '37), senior engineer, electrical engineer department, Public Service Company of Northern Illinois, Chicago, has been appointed chairman of project 1 (application guide of methods for lightning protection of substations) of the lightning protective devices subcommittee of the AIEE protective devices committee for 1948–49.

F. M. Defandorf (A '23, M '37, F '42), senior physicist, National Bureau of Standards, Washington, D. C., has been appointed chairman of project 5 (revise and combine AIEE Standards 24, 28, and 47) of the lightning protective devices subcommittee of the AIEE protective devices committee for 1948–49.

C. E. Nagel (A '46) has joined the McGraw-Hill Book Company as editor of industrial and business books for the mail sales division. He comes to McGraw-Hill from the Westinghouse Electric Corporation, where he was manager of the technical press service. In that capacity, he was responsible for the company's technical and trade magazine articles. A graduate of Stanford University, he worked successively for James McCreery Company and the Champlain Division of the Interchemical Corporation before joining Westinghouse. During World War II he served as a navigator on an attack transport in the Pacific.

Carl Whitmore (A '18), president of the New York (N. Y.) Telephone Company, has been elected president of the Telephone Pioneers of America.

C. H. Black (A '41, M '45), formerly work engineer for the General Electric Company, Philadelphia plant, has been appointed manager of engineering. Mr. Black has been with the company since 1924, and had served in a number of engineering capacities before he was appointed managing engineer of the General Electric Trenton works during the war. He was subsequently named manager of engineering of the switchgear division and then Philadelphia works engineer.

R. R. Wylie (M '46), former district manager for the Roanoke office of the Rumsey Electric Company of Philadelphia, Pa., has resigned to accept a position as operating engineer with Luz Electrica de Barcelona, Barcelona, Venezuela, South America.

R. J. Lusk (A '46), Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed chairman of the subcommittee on aircraft electrical control protective devices, and cable, of the AIEE air transportation committee for 1948–49.

J. H. Ahrens (A '44), formerly company safety engineer, Hartford Electric Light Company, Conn., recently was transferred to the sales department as industrial power consultant.

F. S. Bacon, Jr. (A '37, M '44), formerly manager, central station division department, Westinghouse Electric Corporation, Boston, Mass., has been appointed assistant general sales manager of Rockbestos Products Corporation, New Haven, Conn. In his new post, Bacon will have immediate responsibility for general sales, advertising, and sales promotion of his company's products, which are permanently insulated wire and cable.

H. N. Muller, Jr., (A '37, M '43), manager of graduate student training, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed chairman of the AIEE Student Branches committee for 1948–49.

G. M. L. Sommerman (A '31, M '37), associate professor of electrical engineering, Northwestern Technological Institute, Evanston, Ill., has been appointed chairman of the insulations subcommittee of the AIEE insulated conductor committee for 1948–49.

W. L. Cisler (M '35, F '47), chief engineer of power plants, Detroit (Mich.) Edison Company, has been appointed chairman of the AIEE management committee for 1948–49.

B. G. A. Skrotski (M '45), assistant editor, *Power*, McGraw-Hill Publishing Company, Inc., New York, N. Y., has been appointed chairman of the prime movers subcommittee of the AIEE power generation committee for 1948–49.

M. J. Steinberg (A '24, M '32, F '48), division engineer, system engineering department, Consolidated Edison Company of New York, Inc., has been appointed chairman of the speed governing subcommittee of the AIEE power generation committee for 1948–49.

A. J. Krupy (A '26, F '46), senior engineer, system planning division, Commonwealth Edison Company, Chicago, Ill., has been appointed chairman of the excitation systems subcommittee of the AIEE power generation committee for 1948–49.

A. D. Caskey (A '38, M '45), electrical engineer, Public Service Company of Northern Illinois, Chicago, has been appointed chairman of the station design subcommittee of the AIEE power generation committee for 1948–49.

J. B. McClure (A '29), General Electric Company, Schenectady, N. Y., has been appointed chairman of the hydroelectric systems subcommittee of the AIEE power generation committee for 1948–49.

W. S. Peterson (A '23, F '46), design and construction engineer, water and power department, City of Los Angeles, Calif., has been appointed chairman of the Pacific Coast subcommittee of the AIEE power generation committee for 1948–49.

H. R. Stewart (A '26, M '39, F '46), protection engineer, New England Power Service Company, Boston, Mass., has been appointed chairman of the lightning protective devices subcommittee of the AIEE protective devices committee for 1948–49.

E. R. Whitehead (A '30, F '45), Illinois Institute of Technology, Chicago, has been appointed chairman of project 4 (lightning protection for unit substations) of the lightning protective devices subcommittee of the AIEE protective devices committee for 1948–49.

H. B. Hansteen (A '24, M '43), professor of electrical engineering at Cornell University, Ithaca, N. Y., is on leave for the current academic year to the Brookhaven National Laboratory, Upton, N. Y., as visiting scientist assigned to the nuclear reactor project. Professor Hansteen's affiliation with the Brookhaven Laboratory will be temporary.

R. I. Parker (A '14, M '20) of Chicago, Ill., has been named a commercial vice-president of the General Electric Company, a firm with which he has been connected

since 1912 Prior to his promotion, Parker was manager of the General Electric apparatus department's central district.

G. B. Hoadley (A '35, M '41) of Brooklyn, N. Y., has been appointed professor of electrical engineering at North Carolina State College, Raleigh, N. C. Doctor Hoadley will be the director of graduate work at that institution. He has served on the AIEE instruments and measurements committee from 1942 to the present, and is on the AIEE joint committee of electronic instruments for 1947–48.

L. M. Robertson (A '27, F '45), assistant superintendent of hydro production and transmission of the Public Service Company of Colorado, is the new president of the Colorado Society of Engineers and the vice-president of the Colorado Engineering Council. He was a vice-president of the AIEE from 1945 to 1947, and has served on the following AIEE committees: power transmission and distribution, 1942–46; electric machinery, 1944–46; education, 1945–46.

Wright Canfield (A '31, M '38), formerly the head of the research department of the Public Service Company of Oklahoma, has been appointed assistant to the president of that company. Canfield has been connected with the firm since 1930.

O. A. Browne (A '26), former superintendent of stations, central division, of the Western Massachusetts Electric Company, has been appointed electrical superintendent of stations. He will have immediate charge of system operation, including operation and maintenance of system protective equipment, and will continue to supervise all hydro and primary substations in the division.

L. R. Gaty (A '39, M '43) has been named manager of the Philadelphia (Pa.) Electric Company's engineering department. A graduate of Cornell University, Ithaca, N. Y., Gaty has been in the utility industry since 1923. Prior to his promotion, he served as electric engineer with the company. He was a member of the AIEE power transmission and distribution committee from 1941 to 1944.

F. M. Feiker (M '34, F '42), former dean of the school of engineering, George Washington University, Washington, D. C., has retired as chairman of the division of engineering and industrial research of the National Research Council, Washington, D. C.

W. A. Holland (A '07, M '26) has been appointed to the faculty of the Drexel Institute of Technology, Philadelphia, Pa., as an assistant professor in electrical engineering. A 1903 graduate of Clemson College, S. C., Holland was formerly a professor of electrical engineering at Mackenzie College, São Paulo, Brazil. Since 1923 he has been with the commercial engineering section, switchgear division, of the General Electric Company.

C. F. Craig (M '27) has been named vice-president in charge of the department of operation and engineering of the American Telephone and Telegraph Company. A director of the Bell Laboratories since 1941, and former vice-president in charge of the long lines department, Craig also will be responsible for advice and assistance to Bell Associated Companies and the long line, department on rate and revenue matters.

F. A. Polkinghorn (A '24, M '39) is on personal leave of absence from the systems development department of the Bell Laboratories to permit him to head the research and development division of the Far East Command's Civil Communications Section at Tokyo, Japan. He will be responsible for the direction of all Japanese communications research in government agencies, educational institutions, and private industry. An honor graduate in electrical engineering from the University of California, Polkinghorn is a member of Tau Beta Pi, Sigma Xi, Eta Kappa Nu, and Phi Beta Kappa fraternities. He is also a fellow of the Institute of Radio Engineers.

A. S. Brookes (A '27), engineer, electric distribution department, Public Service Electric and Gas Company, Newark, N. J., has been reappointed chairman of the Standards and publications subcommittee of the AIEE insulated conductor committee for 1948–49.

J. H. Cox (A '25, M '45), engineering manager, Pacific Coast manufacturing and repair department, Westinghouse Electric Corporation, Emeryville, Calif., has been appointed chairman of the West Coast subcommittee of the AIEE electronic power converter committee for 1948–49.

A. J. Maslin (A '42), design engineer, Westinghouse Electric Corporation, Sharon, Pa., has been reappointed chairman of the rectifier transformers subcommittee of the AIEE electronic power converter committee for 1948–49.

D. E. Marshall (A '27, M '33), section engineer, electronics engineering department, Westinghouse Electric Corporation, Bloomfield, N. J., has been reappointed chairman of the rectifying devices subcommittee of the AIEE electronic power converter committee for 1948–49.

(*Continued on page 1121*)

OBITUARY

Lloyd Lester Lee (A '46) electrical engineer with the Consolidated Vultee Aircraft Corporation, San Diego, Calif., died August 14, 1948. Lee was born May 21, 1904, in Boise, Idaho, and received his technical training from the Benson Polytechnic Institute, Portland, Oreg. He was employed in construction work from 1929 to 1931 with the United States Department of Commerce. Lee joined the Westinghouse Electric and Manufacturing Company (now the Westinghouse Electric Corporation), Portland, in 1931 in the heavy service department, and in 1934, went to the construction and maintenance department of the Shell Oil Company's Portland plant. From 1937 to 1940, Lee was on active duty with the United States Army as a lieutenant He joined the Consolidated Vultee Corporation in 1940, but was given leave of absence to return to military service. After his discharge as a major, Lee returned to the Consolidated corporation, and at the time of his death, was group engineer in charge of electrical and radio design for Consolidated Vultee model *420* aircraft. He was an active member of the AIEE San Diego Section.

Franklin J. Champlin (A '20) a division engineer at the General Electric Company's Pittsfield, Mass. plant, died recently. Born September 18, 1888, at Granby, Conn., Champlin received his bachelor of philosophy degree from the Sheffield Scientific School at Yale University in 1911. That same year, he joined the testing department at General Electric's Schenectady, N. Y. plant, and in 1912 was transferred to the electrical transformer engineering department. Champlin was named engineer in charge of the voltage regulator engineering division at Pittsfield, Mass., in 1919, and held this position until his death.

Clifford W. Humphrey (A '03, M '07, F '13), president of the Sayre and Fisher Brick Company, Sayreville, N. J., died July 6, 1948. Born at Waterloo, Wisconsin on March 19, 1878, Humphrey received his degree as an electrical engineer from the University of Wisconsin at Madison in 1900. From 1902 to 1905, he was in charge of the engineering department of the Denver (Colo.) Gas and Electric Company, during which time he was responsible for designing and rebuilding a greater part of the electrical distribution system of Denver and its outlying districts. He was consulting engineer and general manager of the Northern Colorado Power Company, Denver, from 1905 to 1907, and from then until 1913 was a consulting engineer in Chicago, Ill. In 1914, Humphrey became vice-president of the Utilities Power and Light Company, Chicago, Ill., a company he helped organize. Following the first World War, and until 1926, he operated his own laboratory in California, doing research on the manufacture and use of anhydrous aluminum chloride. In 1927, he became vice-president of the Empire Brick Company of New York, and vice-president and general manager of both the Sayre and Fisher Brick Company and Chemicals, Inc., two firms in Sayreville, N. J. He was named president of the Sayre and Fisher Company in 1943. Besides being a life member of AIEE, he was a member of both the American Society of Mechanical Engineers and the American Chemical Society. Humphrey was also a past president of the National Brick Manufacturers Association.

Arthur P. Peterson (A '32, M '45), president and founder of the Control Corporation, Minneapolis, Minn., died July 16, 1948. He was born on May 20, 1894, at Stillwater, Minn., and received his bachelor of science degree in electrical engineering from the University of Minnesota, in 1919. After a short period in the telephone industry, Peterson returned to the university as an instructor of engineering from 1920 to 1923. From the time he left until 1927, he was

field representative for the Association of Electragists International, and followed this with two years as manager of the Maryland Association of Electragists. In 1933, Peterson helped organize the company that became the Control Corporation in 1936. He is the inventor and coinventor of automatic synchronizing equipment, generator voltage regulators, load controls, frequency and supervisory control equipment, telemeters, and other automatic and remote control equipment. Peterson was a member of the AIEE automatic stations committee from 1937 to 1946.

John Emery Lear (A '03, M '30), member of the engineering faculty of North Carolina State College, Raleigh, N. C., since 1938, died at his home in Penland, N. C., on August 17, 1948. A native of Petersburg, Va., he was born July 17, 1879. Professor Lear received degrees in electrical engineering from Virginia Polytechnic Institute in 1901, and from Agricultural and Mechanical College of Texas in 1909. He did advanced work at both Cornell University and the University of Wisconsin. From 1902 to 1905, he worked with the General Electric Company, but began teaching in 1905 at the Agricultural and Mechanical College of Texas. In 1913 and 1914, Lear taught physics and electrical engineering at Norwich University, Northfield, Vt., but during the war years, returned to the General Electric Company. In 1918, he was appointed professor of electrical engineering at the University of North Carolina, Chapel Hill, a position he held until 1928 when he joined the faculty at North Carolina State College. Lear was a member of Sigma Xi fraternity and was chairman of the North Carolina State Board of Registration for Engineers and Surveyors.

Charles F. MacMurray (A '13), vice-president and general manager of the Panama Power and Light Company, Panama, Canal Zone, died August 24, 1948. A native of Starkey, N. Y., he was born September 2, 1879, and was graduated from Syracuse University, Syracuse, N. Y., in 1906. MacMurray went with the Panama utility, an Electric Bond and Share subsidiary, in 1911, and served as general manager from 1922 on.

Leo E. Shire (A '27), export and sales division of the Beech Aircraft Company, Wichita, Kans., died July 31, 1948. Shire was born October 20, 1898, in Mexico, Mo., and was a graduate electrical engineer from the Missouri School of Mines, in 1925. After graduation, he was employed for several years by the electrical division, engineering department, of the Andian National Corporation, Ltd., of Cartagena, Colombia, South America. In recent years Shire had been known widely in the midwest United States, and had been very active in the AIEE Wichita Section.

Charles Gardner Spencer (M '22), formerly with the Bell Telephone Laboratories, New York, N. Y., died at his home August 16, 1948. He was born at Benton Harbor, Mich., and received his technical training at the Lewis Institute, Chicago, Ill. Spencer began with the Western Electric Company, New York, in 1899, first as inspection, and later as development engineer on telephone equipment and apparatus. He remained with that company until 1920 when he went to Sweden to help develop that country's telephone system. In 1923, Spencer returned to the United States and was employed by the Bell Laboratories. He was with that company as development engineer until 1946 when he retired.

Jesse J. Linebaugh (A '06) retired electrical engineer, died August 2, 1948. Linebaugh, who was born in Grove City, Ohio, on January 15, 1877, was an electrical engineering graduate in 1899 from Ohio State University. He was employed by the General Electric Company, Schenectady, N. Y., from 1899 until his retirement in 1946. Linebaugh was especially noted in engineering circles for his invention of the regenerative brake, a device credited with making the operation of electric trains possible. First used in 1911, Linebaugh's brake worked by storing electric energy on down-grades, and releasing it on up-grades.

MEMBERSHIP • • • •

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before November 21, 1948, or January 21, 1949, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Arman, A. N., Pirelli-General Cable Works, Eastleigh, Hants, England

1 to grade of Fellow

To Grade of Member

Ahlers, B. H., Electro Switch Corp., Weymouth, Mass.
Batra, R. N., Public Works Dept., West Punjab, Pakistan, India
Braun, E. H. (re-election), Consolidated Edison Co. of N. Y., New York, N. Y.
Burchard, W. K., Illinois Bell Tel. Co., Chicago, Ill.
Burmaster, K. E., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Caylor, G., 1309 Crestwood Rd., Austin, Tex.
Conrad, E., Glenex Laboratory, Phoenix, Ariz.
Gale, J. G., Daniel Smilo & Sons, Inc., New York, N. Y.
Goyne, J. C., E. I. du Pont de Nemours & Co., Wilmington, Del.
Hall, J. C., The Goodyear Tire & Rubber Co., Akron, Ohio
Hanft, H. H., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Harkness, M. A., Brazos River Transmission Elec. Corp., Inc., Waco, Tex.
Hoffman, G. N., Duquesne Light Co., Pittsburgh, Pa.
Horth, W. S., Apex Elec. Mfg. Co., & Reliance Elec. & Eng. Co., Cleveland, Ohio
Huguet, F. C., H. K. Ferguson Co., New York, N. Y.
Kenny, B. M., Waterous Ltd., Brantford, Ontario, Canada
Lamb, E. B., Ebasco Services, Inc., New York, N. Y.
Mehta, G. D., Ministry of Defense, Dinapore, N. Bihar, India
Muntz, G., Jr., Tropenas Co., New York, N. Y.
O'Shea, F., Pollaphuca Generating Station Co., Kildare, Ireland
Schumann, R., Precise Products Co., Racine, Wis.
Shew, E. B., Philadelphia Elec. Co., Philadelphia, Pa.
Spry, P., Public Works Dept., Nukualofa Tonga, Friendly Islands
Steele, C. P., Boeing Airplane Co., Seattle, Wash.
Vickrey, H. H., The Commonwealth & Southern Corp., Birmingham, Ala.
Warman, W. C., The Chesapeake & Potomac Tel. Co., Washington, D. C.
West, C. O., 3058 Glendale Blvd., Los Angeles, Calif.

27 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Douglass, M. E., General Elec. Co., West Lynn, Mass.
Gaines, B., Dictaphone Corp., Bridgeport, Conn.
Heydt, H. L., Univ. of Connecticut, Storrs, Conn.
Johnstone, G. E., Walter J. Rider Co., Inc., Binghamton, N. Y.
Liao, T-W., General Elec. Co., Pittsfield, Mass.
Loveland, H. A. (re-election), N. Y. State Elec. & Gas Corp., Johnson City, N. Y.
Moss, W. M., Stevens Paper Mills, Westfield, Mass.
Munroe, K. A., Jackson & Moreland, Boston, Mass.
Murphy, W., General Elec. Co., Pittsfield, Mass.
Spencer, J. H., General Elec. Co., Lynn, Mass.
Underwood, H. S., Central New York Power Corp., Utica, N. Y.
Young, C. T., Intl. Business Machines, Endicott, N. Y.

2. Middle Eastern

Borisch, T. V., Curtiss-Wright Corp., Columbus, Ohio
Boughton, J. K., Goodyear Tire & Rubber Co., Akron, Ohio
Gibson, R. C., USAF Institute of Tech., Dayton, Ohio
Gigante, M., National Elec. Coil Co., Columbus, Ohio
Heredia, F. M. F., American Car & Foundry Co. "Patentes Talgo S. A.," Berwick, Pa.
Jagannathan, A. R., General Elec. Co., Philadelphia, Pa.
Lynd, J. M. (re-election), Federal Power Comm., Washington, D. C.
Ratcliff, F. W., Jr., American Tel. & Tel. Co., Pittsburgh, Pa.
Rose, J. E., General Elec. Co., Akron, Ohio
Shook, W. R., Jr., Elec. Machinery Mfg. Co., Cleveland, Ohio
Stocking, M. H., Philco Corp., Philadelphia, Pa.
Wagner, B. B., Pennsylvania Elec. Co., Seward, Pa.
Wolfe, E. V., Allis-Chalmers Mfg. Co., Baltimore, Md.
Yakura, J. N., Rockwell Mfg. Co., Pittsburgh, Pa.

3. New York City

Aaronson, H. O., The H. K. Ferguson Co., New York, N. Y.
Cook, S., C. & W. Radio & Appliance Co., Pearl River, N. Y.
Feder, H., Bell Tel. Labs., New York, N. Y.
Glosser, D., General Elec. Co., Trenton, N. J.
Johnson, C. E. (re-election), Consolidated Edison Co., Inc., Brooklyn, N. Y.
Kessner, F. L., Westchester Lighting Co., Mt. Vernon, N. Y.
Rider, C. E., Central Hudson Gas & Elec. Corp. Poughkeepsie, N. Y.
Salmonson, W. G., Pennsylvania Railroad Co., New York, N. Y.
Sten, O. J., Jersey Central Power & Light Co., Allenhurst, N. J.
Timberman, C. G., N. Y. Tel. Co., New York, N. Y.
Welan, I., C. & W. Radio, & Appliance Co. Pearl River, N. Y.

4. Southern

Abele, R. K., Oak Ridge National Lab., Oak Ridge, Tenn.
Adams, W. D., Davis H. Elliot Co., Inc., Roanoke, Va.
Bedwell, W. W., Jr., Knoxville Utilities Board, Knoxville, Tenn.
Bledsoe, I. I., U. S. Navy Dept., Naval Base, S. C.
Bull, I. S., Jr., Dunean Mills, Greenville, S. C.
Cade, M. J. (re-election), New Orleans Public Service Inc., New Orleans, La.
Casey, B. D., Jr., General Elec. Co., New Orleans, La.
Flowers, R. B., General Elec. Co., Atlanta, Ga.
Jeffords, A. U., Alabama Power Co., Birmingham, Ala.
Jones, C. C., South Carolina Power Co., Charleston, S. C.
King, R. F., Oak Ridge National Lab., Oak Ridge, Tenn.
McClure, W. H., Alabama Power Co., Birmingham, Ala.
Pickell, J., Jr. (re-election), Southern Bell Tel. & Tel. Co., Charleston, S. C.
Reese, S. W., Southern Bell Tel. & Tel. Co., Jacksonville, Fla.
Russell, W. L., E. I. Du Pont, Martinsville, Va.

5. Great Lakes

Betz, W. G., Commonwea th Edison Co., Chicago, Ill.
Franklin, D. E., Caterpillar Tractor Co., East Peoria, Ill.
Gasior, C. P., Commonwealth Edison Co., Chicago, Ill.
Gaston, L. D., Veterans Admin., St. Paul, Minn.
Johnson, A. H., King Midas Flour Mills, Minneapolis, Minn.
Perrino, S., Westinghouse Elec. Corp., Chicago, Ill.
Tosch, H. P., Commonwealth Edison Co., Chicago Ill.

7. South West

Buckman, J. B., Emerson Elec. Mfg. Co., St. Louis, Mo.
Carroll, J. D. (re-election), Federal Power Comm. Ft. Worth, Tex.
Everson, C. W., General Elec. Co., Little Rock, Ark.
Floyd, R. H., The L. E. Myers Co., Longview, Tex.
Hudson, A. C., Southwestern Public Service Co., Guymon, Okla.
Kinney, A. L., Kansas Gas & Elec. Co., Wichita, Kans.
Seneff, W. M., Century Elec. Co., St. Louis, Mo.
Smith, B. W., Southwestern Public Service Co., Amarillo, Tex.
Tandy, F. R., Southwestern Bell Tel. Co., Dallas, Tex.

Viola, A. G. (re-election), Wagner Elec. Corp., Kansas City, Mo.
Woods, W. A., Clark Controller Co., St. Louis, Mo.

8. Pacific

Arnold, T. E., Sacramento Air Materiel Area, McClellan Field, Calif.
Fellows, R. C., Pacific Gas & Elec. Co., Oakland, Calif
Holst, M. H., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Poole, H. H. (re-election), War Dept. (DAC) Hqs. KBC, c/o Postmaster, San Francisco, Calif.
Yager, C. L., Pacific Gas & Elec. Co., San Francisco, Calif.

9. North West

Becker, O. N., Pacific Power & Light Co., Portland, Oreg.
Begley, D. B., Newbery-Neon Elec. Co., Richland, Wash.
Carlson, R. J., Graybar Elec. Co., Seattle, Wash.
Chitty, L. M., Puget Sound Power & Light Co., Seattle, Wash.
Hildebrandt, L. H., General Elec. Co., Richland, Wash.
King, H. L., Bonneville Power Admin., Portland, Oreg.
Schindele, W. J., Bonneville Power Admin., Portland, Oreg.

10. Canada

Fenrick, M. J., Krumm, Young & Co., Ltd., Toronto, Ontario, Canada
Stangeland, K., Shawinigan Water & Power Co., LaTuque, Quebec, Canada

Elsewhere

Hargreaves, H. R., Johnson & Phillips, Ltd., Charlton, London, England
Joseph, V. J., Ferranti Ltd., Hollinwood, England
Paninski, E. A., Schlumberger Surenco, Caracas Venezuela, South America
Parrinello-S. R., Escuela N. de Ingenieros, Lima, Peru, South America
Quin, J. G., County Council of Middlesex, Westminster, England
Snelson, J. W., Turners Asbestos Cement Co., Ltd., Trafford Park, Manchester, England

Total to grade of Associate
United States and Canada, 84
Elsewhere, 6

Recommended for Transfer

The board of examiners at its meetings of September 16, 1948 and September 30, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Beverage, H. H., director radio systems research RCA Labs. Div.; vice pres. chg. of research & development RCA Communications, Inc., New York, N. Y.
Blankenbuehler, J. H., engr., Hobart Bros. Co., Troy, Ohio
Boughton, W. V., vice pres., gen. mgr., Phaostron Co., South Pasadena, Calif.
Callahan, J. L., asst. to director, radio systems lab.; vice pres., research & development, RCA Communications, Inc., New York, N. Y.
Carlin, P. J., distribution supt., Florida Pr. & Lt. Co., Miami, Fla.
Coggeshall, I. S., gen. traffic mgr., Western Union Telegraph Co., New York, N. Y.
Cole, F. H., pres. & gen. mgr., Cole Electric Co., Culver City, Calif.
Cozzens, B., principal elec. engr., Dept. of Water & Pr., Los Angeles, Calif.
DeBoer, D. J., executive mgr., Copper Wire Engg. Assn., Washington, D. C.
Goodwin, V. E., managing engr., lightning arrester cutout & capacitor engg. div., General Elec. Co., Pittsfield, Mass. (recently retired)
Hamburger, F., Jr., elec. engg. professor, The Johns Hopkins Univ., Baltimore, Md.
Herzog, E., principal elec. engr., U. S. Air Forces, engg. div., Wright Field, Dayton, Ohio
Hough, E. L., chief design engr., Union Elec. Co. of Mo., St. Louis, Mo.
Hubbard, H. S., div. engr., power transformer engg. div., General Elec. Co., Pittsfield, Mass.
Michell, H. G., gen. mgr., Bolivian Pr. Co., Ltd., La Paz, Bolivia
Moreland, H. D., mgr., x-ray div., Westinghouse Elec. Corp., Baltimore, Md.
Morris, E. W., mgr. district engg. & service div., Westinghouse Elec. Corp., Los Angeles, Calif.
Opsahl, A. M., design engr. on lightning arresters, Westinghouse Elec. Corp., East Pittsburgh, Pa.
Paluev, K. K., developmental engr., transformer div., General Electric Co., Pittsfield, Mass.
Paxton, R., mgr., transformer & allied products div., General Electric Co., Pittsfield, Mass.
Sawyer, M. A., protection engr., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Stratford, J. P., engr. of station design, Dept. of Water & Power, Los Angeles, Calif.
Sweetnam, A. H., consultant & manufacturers agent, 616 Little Bldg., Boston, Mass.
Treanor, E. D., Jr., executive engr., distribution trans. engg. div., General Elec. Co., Pittsfield, Mass.
Triplett, H. A., power switching equipment engr., A. B. Chance Co., Centralia, Mo.
Vivian, J. H., elec. & mech. maintenance engr., Southern California Edison Co., Los Angeles, Calif.
Walker, J. R., regional power mgr., U. S. Bureau of Reclamation, Billings, Mont.
Wetherill, L., engr-in-charge, bushing engg. div., General Elec. Co., Pittsfield, Mass.
28 to grade of Fellow

To Grade of Member

Adams, A. R., div. engr., Iowa Power & Lt. Co., Red Oak, Ia.
Armington, R. E., asst. prof. elec. engg., Pennsylvania State College, State College, Pa.
Batchelder, D. E., elec. engr., Lane-Wells Co., Los Angeles, Calif.
Bates, G., consulting & application engr., Westinghouse Elec. Corp., Seattle, Wash.
Beam, R. E., assoc. prof., elec. engg., Northwestern Univ., Evanston, Ill.
Beckwith, R. W., elec. engr., General Elec. Co., Syracuse, N. Y.
Boghosian, E., elec. engr., Navy Dept., Bureau of Ships, Washington, D. C.
Borgstadt, R. D., consulting & application engr. Westinghouse Electric Corp., Chicago, Ill.
Brennan, T. J., elec. engr., Voohrees, Walker, Foley & Smith, New York, N. Y.
Bridge, J. A., elec. engr., Corbett, Tinghir & Co., New York, N. Y.
Brown, J. E., pres., Brown & Heim, Inc., Baltimore, Md.
Carlson, A. E., chief engr., Kurz & Root Co., Appleton, Wis.
Cawthorne, T. S., sales engr., Manufacturers' Representative, Detroit, Mich.
Cherrick, I. L., electronics engr., Naval Research Lab., Washington, D. C.
Cranmer, J. P., engr. Midlands Area, British Thomson Houston Co., Birmingham, England
Crooker, P. R., development engr., wired radio div., Line Material Co., East Stroudsburg, Pa.
Denton, S. M., engr., bureau of reclamation, Denver Federal Center, Denver, Colo.
Doncyson, R. A., elec. engr., General Elec. Co., Syracuse, N. Y.
Dunkelman, L., physicist, micro waves sec., Naval Research Lab., Washington, D. C.
Durand, S. R., application engr., Allis-Chalmers Mfgr. Co., Pacific Regional Office, San Francisco, Calif.
Evans, W. R., asst. prof., elec. engg., Washington Univ., St. Louis, Mo.
Fromke, F. A., assoc. engr., Rural Electrification Adm., U. S. Dept. of Agriculture, Washington, D. C.
Ghosh, C. S., engr. on training, Hydro-Electric Pr. Comm. of Ontario, Toronto, Ont., Can.
Giesler, L. P., physicist, Naval Ordnance Lab., White Oak, Md.
Glogau, M. L., design engr., Allen-Bradley Co., Milwaukee, Wis.

(*Continued on page 1120*)

Section and Branch Activities—Annual Report for 1947-1948

The following constitutes the annual report on Institute Section and Branch activities for the fiscal year which ended April 30, 1948. Similar information for three preceding fiscal years appeared in *ELECTRICAL ENGINEERING* in August 1947, pages 837–40; July 1946, pages 352–4; June 1945, pages 228–9.

Members of the 1947–1948 committees supervising the divisions of Institute activities covered by this report are

Sections—J. C. Strasbourger, *chairman;* R. E. Kistler, *vice chairman;* H. W. Sussman, *secretary;* D. I. Anzini, F. S. Black, L. T. Blaisdell, G. W. Bower, S. C. Commander, T. H. Crosby, McNeely Du Bose, W. A. Dynes, V. P. Hessler, C. P. Knost, C. W. Lethert, E. F. Lopes, C. W. Mier, A. C. Muir, J. H. Pilkington, Roland G. Porter, C. S. Purnell, Victor Siegfried, E. W. Stone, and ex officio, chairmen of Sections.

Student Branches—J. F. Calvert *chairman;* E. M. Strong, *vice chairman;* Sterling Beckwith, A. M. Harrison, P. L. Hoover, A. H. Howell, J. H. Kuhlmann, Everett S. Lee, W. H. Pickering, L. T. Rader, R. W. Warner, B. S. Willis, and C. R. Wischmeyer.

Table I. Section Membership and Meetings During Year Ending April 30, 1948

Section	AIEE Members August 1947	AIEE Members August 1948	Number of Meetings	Total No. Meetings
Akron	97	109	8	
Groups: Electronics			2	
Industrial practice			2	
Power distribution			1	
Subsection: Canton			3	16
Alabama	135	158	9	9
Arizona	97	112	9	
Groups: Distribution			2	
Electronics			2	
Meter and relay			1	
Power			3	17
Arkansas	54	77	8	8
Arrowhead	34	39	9	9
Beaumont	73	78	10	
Group: Transmission and distribution of power			2	12
Boston	766	803	8	
Groups: Basic science			2	
Distribution			2	
Electronics			2	
Industrial power applications			3	
Instruments and measurements			1	
Insulation			2	
Land transportation			3	
Power generation			1	
Transmission			1	
Wire communications			2	27
Canton	59	69	6	6
Central Indiana	197	222	10	10
Chicago	1,370	1,487	4	

Table I (Continued). Section Membership and Meetings During Year Ending April 30, 1948

Section	AIEE Members August 1947	AIEE Members August 1948	Number of Meetings	Total No. Meetings
Groups: Basic science			3	
Communication			4	
Electronics			4	
Industrial			6	
Power			5	26
Cincinnati	198	205	9	
Group: Technical discussion			6	15
Cleveland	583	629	10	
Groups: Electrical measurements			4	
Motors and control			8	
Basic science			2	24
Columbus	116	131	10	
Subsection: Zanesville			11	21
Connecticut	475	492	7	7
Dayton	273	300	10	
Groups: Electrical engineering in aeronautics			4	
Industrial electronics			4	
Motors and controls			2	20
Denver	325	338	9	
Groups: Communications			6	
Electric equipment			7	
Electronics			3	
Industrial applications and processes			1	
Instruments and measurements			5	
Power systems			5	
Subsection: Casper			8	44
East Tennessee	290	342	26	
Group: Technical			4	30
Erie	110	120	7	7
Florida	181	225	2	
Subsections: Jacksonville			1	
Miami			5	
West Coast			2	10
Fort Wayne	124	114	8	8
Georgia	193	207	8	8
Houston	228	246	9	
Groups: Communications			4	
Industrial applications			2	
Subsection: Freeport			10	25
Illinois Valley	92	117	16	
Group: Technical			13	29
Iowa	126	159	11	
Subsection: Quad Cities			8	19
Ithaca	112	158	10	
Subsection: Binghamton Area			7	
Binghamton Area technical group			2	19
Kansas City	221	228	11	
Groups: Electronics			1	
Human aspects of engineering			7	
Industrial practices			6	
Meters and relays			9	34
Lehigh Valley	215	281	9	9
Los Angeles	900	1,179	10	
Groups: Aircraft			8	
Electronics			3	
Power			9	
Subsection: Boulder City			8	38
Louisville	82	110	8	8
Lynn	217	228	22	22
Madison	90	82	9	9
Mansfield	60	68	8	8
Maryland	448	536	10	
Groups: Communications			1	
Electric power			1	
Industrial electronics			3	
Subsection: Lancaster-York			7	22
Memphis	117	106	10	10
Mexico	209	202		
Michigan	652	695	10	
Round table meetings			6	
Groups: Electronics			1	
Industrial power			1	
Instruments and measurements			3	
Welding			6	
Subsection: Saginaw Valley			11	38

Table II. Branch Meetings Held

Branch	Number
Akron, University of	11
Alabama Polytechnic Institute	13
Alabama, University of	10
Alberta, University of	10
Arizona, University of	25
Arkansas, University of	13
British Columbia, University of	21
Brooklyn, Polytechnic Institute of	
Day division	—
Evening division	1
Brown University	—
Bucknell University	12
California Institute of Technology	13
California, University of	11
Carnegie Institute of Technology	25
Case Institute of Technololgy	15
Catholic University of America	4
Cincinnati, University of	4
Clarkson College of Technology	11
Clemson Agricultural College	13
Colorado A & M College	9
Colorado, University of	6
Columbia University	3
Connecticut, University of	7
Cooper Union	
Day division	15
Evening division	2
Cornell University	8
Delaware, University of	4
Denver, University of	12
Detroit, University of	1
Drexel Institute of Technology	4
Duke University	38
Florida, University of	7
George Washington University	5
Georgia Institute of Technology	1
Harvard University	3
Idaho, University of	20
Illinois Institute of Technology	11
Illinois, University of	10
Chicago division	9
Iowa State College	19
Iowa, University of	29
Johns Hopkins University	28
Kansas State College	39
Kansas, University of	11
Kentucky, University of	15
Lafayette College	7
Lehigh University	9
Louisiana State University	6
Louisville, University of	10
Maine, University of	6
Manhattan College	4
Marquette University	5
Maryland, University of	9
Massachusetts Institute of Technology	5
Michigan College of Mining & Technology	9
Michigan State College	5
Michigan, University of	23
Milwaukee School of Engineering	10
Minnesota, University of	10
Mississippi State College	11
Missouri School of Mines & Technology	8
Missouri, University of	6
Montana State College	11
Nebraska, University of	9
Nevada, University of	7
New Hampshire, University of	6

Table III. Branch Meetings Held

Number of Branches	
Number of meetings held	
Average number of meetings	
Total attendance	
Average attendance per meeting	

During Year Ending April 30, 1948

Branch	Number
New Mexico State College	8
New Mexico, University of	4
New York, College of the City of	21
New York University	
Day division	5
Evening division	5
Newark College of Engineering	3
North Carolina State College	11
North Dakota State Agricultural College	11
North Dakota, University of	9
Northeastern University	14
Northwestern University	10
Norwich University	—
Notre Dame, University	11
Ohio Northern University	19
Ohio State University	6
Ohio University	5
Oklahoma Agricultural and Mechanical College	9
Oklahoma, University of	8
Oregon State College	2
Pennsylvania State College	4
Pennsylvania, University of	6
Pittsburgh, University of	28
Pratt Institute	11
Princeton University	6
Puerto Rico, University of	4
Purdue University	7
Rensselaer Polytechnic Institute	3
Rhode Island State College	11
Rice Institute	5
Rose Polytechnic Institute	13
Rutgers University	1
Santa Clara, University of	1
South Carolina, University of	16
South Dakota School of Mines & Technology	3
South Dakota State College	7
Southern California, University of	13
Southern Methodist University	6
Stanford University	13
Stevens Institute of Technology	—
Swarthmore College	8
Syracuse University	11
Tennessee, University of	18
Texas, Agricultural and Mechanical College of	13
Texas Technological College	14
Texas, University of	15
Toronto, University of	7
Tufts College	5
Tulane University	—
Union College	10
Utah, University of	9
Vanderbilt University	5
Vermont, University of	13
Villanova College	7
Virginia Military Institute	9
Virginia Polytechnic Institute	12
Virginia, University of	4
Washington State College	18
Washington, University of	4
Washington University	9
Wayne University	3
West Virginia University	4
Wisconsin, University of	10
Worcester Polytechnic Institute	9
Wyoming, University of	12
Yale University	6
Total Branches, 127	1,233

During Last Three Fiscal Years

	Fiscal Year Ending April 30		
	1946	1947	1948
....	125	126	127
....	718	1,031	1,233
....	6	8	10
....	23,473	61,026	77,224
....	33	59	63

Table I (Continued). Section Membership and Meetings During Year Ending April 30, 1948

Section	AIEE Members August 1947	AIEE Members August 1948	Number of Meetings	Total No. Meetings
Milwaukee	553	621	9	
Groups: Basic science			4	
Electric machinery			3	
Electronics			5	
Power application and control			3	
Transmission and distribution			3	
Subsection: Fox River Valley			6	33
Minnesota	212	240	14	
Subsection: Red River Valley			6	20
Montana	85	84	8	
Subsection: Great Falls			9	17
Montreal	262	308	11	
Subsections: Ottawa			11	
Ottawa hydroelectric systems group			4	
St. Maurice Valley			2	28
Muscle Shoals	24	23	4	4
Nebraska	72	85	6	6
New Mexico-West Texas	76	108	12	
Group: Technical			2	14
New Orleans	181	210	11	
Subsections: Baton Rouge			7	
Lake Charles			9	
Shreveport			1	28
New York	4,509	4,715	7	
Groups: Basic science			4	
Communication			9	
Illumination			5	
Power and industrial			11	
Transportation			3	
Subsections: Hudson Valley			5	
New Jersey			11	
San Juan			2	57
Niagara Frontier	268	249	8	
Subsection: Niagara Falls			2	10
North Carolina	187	206	3	
Subsection: Charlotte			7	10
North Texas	264	307	11	
Groups: Electronics Communications			4	
Industrial Electronics			1	
Industrial Practices			1	
Subsections: Fort Worth			7	
Panhandle			1	
West Central Texas			4	29
Oklahoma City	159	168	9	
Groups: Communications			3	
Electronics			4	
Industrial practices			6	
Instruments and measurements—Servomechanism			1	
Power systems			5	28
Panhandle Plains	70	89	8	8
Philadelphia	1,176	1,248	11	
Groups: Trenton discussion			1	
Basic sciences			3	
Communications			4	
Electronics			3	
Industrial practice			3	
Instruments and measurements			3	
Power systems			3	
Subsection: Wilmington			9	
Wilmington discussion group			2	42
Pittsburgh	822	916	14	14
Pittsfield	225	240	11	
Group: Electronics			5	16
Portland (Oreg.)	382	407	27	27
Providence	127	129	9	9
Rochester	180	204	15	
Groups: Communication			1	
Power			1	17
Rock River Valley	51	69		
St. Louis	413	446	11	
Groups: Electronics			10	
Illumination			1	
Industrial power practices			9	31
San Diego	124	150	11	
Group: Electronics			2	31

Table 1 (Continued). Section Membership and Meetings During Year Ending April 30, 1948

Section	AIEE Members August 1947	AIEE Members August 1948	Number of Meetings	Total No. Meetings
San Francisco	946	1,137	27	
Subsections: Fresno			8	
Red Bluff			1	
Sacramento			12	
San Jose			7	
Shasta			7	62
Schenectady	764	839	9	
Groups: Basic sciences			4	
Electric welding			3	
Industrial electronics			4	
Industrial power			2	
Power generation and transmission			2	
Transportation			4	28
Seattle	330	374	10	
Groups: Aircraft			5	
Electronics			2	
Power			3	20
Sharon	144	158	9	9
Shreveport	54	65	8	8
South Bend	85	95	10	
Group: Technical			5	15
South Carolina	66	86	2	
Subsection: Charleston			3	5
South Texas	101	131	9	
Subsection: Corpus Christi			4	13
Spokane	142	125	11	
Group: Technical			5	16
Springfield	78	93	12	
Group: Technical			5	17
Syracuse	187	203	8	8
Toledo	97	103	10	10
Toronto	513	509	15	
Groups: Communications			5	
Discussion			11	
Subsections: Hamilton			10	
Niagara			5	46
Tulsa	113	101	7	
Group: Technical			4	11
Urbana	74	88	10	10
Utah	103	110	9	9
Vancouver	143	167	11	
Group: Electronics			8	19
Virginia	178	210	3	
Subsections: Hampton Roads			8	
Richmond			2	
Western Virginia			4	17
Washington	772	790	8	
Groups: Communications			4	
Electrical research			4	
Electronics			4	
Mathematics			3	
Power			2	25
West Virginia	96	102	10	10
Wichita	84	86	13	13
Worcester	78	81	7	7
	25,338	27,527		1,463

Total Sections, 81
Total technical groups, 111
Total Subsections, 41
Total attendance, 119,943

Table IV. Section Meetings Held During Last Three Fiscal Years

	Fiscal Year Ending April 30		
	1946	1947	1948
Number of Sections	75	75	81
Number of meetings held	1,187	1,370	1,463
Average number of meetings	16	18	18
Total attendance	116,294	154,943	119,943
Average attendance per meeting	98	113	82

(Continued from page 1117)

Gordon, D. I., elec. engr., Naval Ordnance Lab., Naval Gun Factory, Washington, D. C.
Hanson, L., asst. chief electrician Consolidated Coppermines Corp.; consulting elec. engr., Eureka Corp., Ltd., Kimberly, Nev.
Harding, G. R., liaison engr., English Elec. Co., foreign engg. dept., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Hembree, H. G., elec. engr., Rural Electrification Adm., Washington, D. C.
Hinch, W. H., elec. engr., U. S. Bureau of Reclamation, Denver Federal Center, Denver, Colo.
Horn, F. C., elec. design engr., The Lima Elec. Motor Co., Lima, Ohio
Huette, W. F., application engr., Allen-Bradley Co., Milwaukee, Wis.
Hurd, C. T., mgr., Public Utility District 1, Cowlitz County, Longview, Wash.
Jones, T. B., asst. prof., elec. engg., The Johns Hopkins Univ., Baltimore, Md.
Ledbetter, G. W., district engr., West Coast, Luminator, Inc., Van Nuys, Calif.
Leggett, A. B., captain, U. S. Navy, Office Chief of Naval Operations; Ship Command Member, Ship Characteristics Board, Washington, D. C.
Leonardon, E. G., director, Schlumberger Well Surveying Corp., Houston, Tex.
Lindbeck, S. L., marine & avia. elec. engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Ludekens, L. E., electronic engr., Southern California Edison Co., Los Angeles, Calif.
March, L. A., designing engr., General Elec. Co., Fort Wayne, Ind.
Marsden, D. J., consulting & application engr., Westinghouse Elec. Corp., San Francisco, Calif.
Mead, S. P. (Mrs.), member of technical staff, Bell Tel. Labs., Inc., New York, N. Y.
Michael, D. T., electric distribution engr., Cincinnati Gas & Elec. Co., Cincinnati, Ohio
Mitchell, F. T., Jr., senior radio engr., Jansky & Bailey, Washington, D. C.
Morreall, H. W., supt. of plant, Pennsylvania Pr. & Lt. Co., Mount Carmel, Pa.
Mueller, F. M., elec. supervisor, Stone & Webster Engg. Corp., San Francisco, Calif.
Mulberry, F. L., Jr., district mgr., Reynolds Electrical & Engg. Co., Albuquerque, N. M.
Neuber, R. E., asst. engr., Collins Radio Co., Ceda Rapids, Ia.
O'Brien, E. J., assoc. prof., Southern Methodist Univ., Dallas, Tex.
Packer, L. C., section head, motor design. Westinghouse Elec. Corp., East Springfield plant, Springfield, Mass.
Pallange, E. P., elec. engr., P-6, Navy Dept., Bureau of Ships, Washington, D. C.
Palmer, J. E., technical estimator, Pacific Gas & Elec. Co., Salinas, Calif.
Pelster, A. F., sales engr., Westinghouse Elec. Corp., Lima, Ohio
Powell, A. H., designing engr., General Elec. Co., Phila., Pa.
Ray, J. J., engr., Philadelphia Elec. Co., Phila., Pa.
Rowell, R. M., section engr. on switchboard instruments General Elec. Co., West Lynn, Mass.
Rucker, G. F., field engr., Leeds & Northrup Co., Los Angeles, Calif.
Runkle, L. D., asst. prof., elec. engg., Rensselaer Polytechnic Inst., Troy, N. Y.
St. Andre, J. W., elec. supervisor, Wright Aeronautical Corp., Woodridge, N. J.
Schultheis, T. W., elec. designer, American Cyanamid Co., New York, N. Y.
Simpson, J. L., Jr., elec. engr., Marr & Holman, Nashville, Tenn.
Smith, J. R., factory engr., Pennsylvania Transformer Co., Cannonsburg, Pa.
Snyder, H. W., instructor, Montana State College, Bozeman, Mont.
Staehle, P. M., sales mgr., specialty trans. & ballast divs., General Elec. Co., Fort Wayne, Ind.
Steinert, E. E., chief engr., Navy Dept., Bureau of Ships, Washington, D. C.
Stephenson, J. G., engr., Airborne Instruments Lab., Inc., Mineola, N. Y.
Storm, H. F., elec. engr., General Elec. Co.; (asst. prof., Rensselaer Poly. Inst.) Schenectady, N. Y.
Tangel, J. E., elec. designer, Public Service Elec. & Gas Co., Newark, N. J.
Tellwright, F. D., vice pres. & genl. mgr., Oregon area, The Pacific Tel. & Tel. Co., Portland, Oreg.
Van Horn, R. H., member of technical staff, Bell Tel. Labs., Inc., New York, N. Y.
Vaughan, V. G., vice pres. Metals & Controls Corp.; manager, Spencer Thermostat Co., Attleboro, Mass.
Vierheller, A. P., power engr., Union Electric Co. of Missouri, St. Louis, Mo.
Weber, R. S., president, Weber-Thompson Construction Co., Dallas, Tex.
Weckwerth, H. F., manager, City of Kaukauna Electrical & Water Depts., Kaukauna, Wis.
Wells, C. A., transmission & protection engr., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Whinery, W. D., Jr., vice-pres., The Tide Co., Tacoma, Wash.
Whitehouse, T. S., project engr., Patchen & Zimmerman, Engineers, Box 241, Oak Ridge, Tenn.
Wilcox, J. L., asst. vice-pres., Western Union Tel. Co., New York, N. Y.
Williams, M. D., service engr., Allis-Chalmers Mfgr. Co., San Francisco, Calif.
Williams, R. E., Jr., application engr., Westinghouse Elec. Corp., Birmingham, Ala.
Woodson, R. K., asst. supt. underground dept., Kansas City Pr. & Lt. Co., Kansas City, Mo.

81 to grade of Member

PERSONALS (*Continued from page 1115*)

H. H. Spencer (A '25), manager of Teleran sales, Radio Corporation of America, has received the Presidential Certificate of Merit for his work as chief of the guided missiles division of the Office of Scientific Research and Development during World War II.

J. W. Butler, technical consultant for the General Electric commercial engineering division, has been named manager of that division. He has been with the company since 1926, and has had extensive experience in several fields, including motor and generator design, central station engineering, and capacitator engineering and application. Also promoted was **C. E. Sutton, Jr.** (A '39, M '45), former transformer engineer, to the new post of assistant manager, power transformer sales division. Sutton has been with General Electric since 1935, following his graduation from Emory University. He has been in various departments dealing with transformers since joining the company.

W. L. Everitt (A '25, F '36), head of the department of electrical engineering, University of Illinois, will become dean of the University's College of Engineering effective September 1, 1949. An electronic engineer of note, Everitt has taught engineering at several schools since 1926. During World War II, he was chief of operational research for the War Department.

L. E. Rau (A '46), formerly of the New York district office of the Joshua Hendy Corporation, has been named manager of that company's recently opened Buffalo, N. Y., branch office.

V. K. Zworykin (M '22, F '45), vice-president and technical consultant of the Radio Corporation of America Laboratories, Princeton, N. J., has received the Presidential Certificate of Merit for outstanding services to the United States during World War II. Doctor Zworykin was given the award for his work with the division of optics and other sections of the National Defense Research Committee.

A. W. Robertson (A '27), chairman of the board, Westinghouse Electric Corporation, has been named chairman of the board of the Baldwin Locomotive Works, Philadelphia, Pa.

E. W. Jones (A '39), formerly assistant professor of electrical engineering at Pennsylvania State College, was recently named associate professor of electrical engineering at the Illinois Institute of Technology.

Joel Tompkins (A' 30), electrical engineer, Aluminum Company of America, Massena, N. Y., has been reappointed cochairman of the electronic converter application subcommittee of the AIEE electronic power converter committee for 1948–49.

L. W. Morton (A' 38, M '45), head of the new power electronics divisions, General Electric Company, Schenectady, N. Y., has been reappointed chairman of the electronic converter application subcommittee of the AIEE electronic power converter committee for 1948–49.

L. Milton (A '41), formerly senior engineer at the Solar Manufacturing Corporation, North Bergen, N. J., is now chief engineer at the Filtron Company, Inc., Bayside, N. Y.

A. A. Emlen (A '28), formerly vice-president in charge of engineering at the American Transformer Company and the Newark Transformer Company, has joined the engineering staff of the Peerless Electrical Products division of Altec Lansing Corporation, New York, N. Y.

B. A. Fisher (M '45), formerly electrical engineering professor at the University of Denver, Colo., was recently appointed associate professor at the Illinois Institute of Technology.

L. W. Matsch (M '41), former supervisor in electrical engineering research at the Armour Research Foundation, Chicago, Ill., has been appointed professor of electrical engineering at the Illinois Institute of Technology.

I. E. Ross, Jr. (M '44), former chief engineer for the Victor Electric Company, Cincinnati, Ohio, has been named assistant division engineer of the d-c and specialty motors division of the FHP motor engineering divisions of the General Electric Company, Fort Wayne, Ind.

G. P. Lehmann (A '35), former manager of the General Electric Company's plastics division, Pittsfield, Mass., has been named to the personal staff of **Doctor Zay Jeffries** (M '36, F '42), vice-president of that company.

C. S. Cole (A '30, M '45), former superintendent, electrical and mechanical maintenance, Niagara Falls (N. Y.) Power Company, has been named superintendent of hydroelectric generation for that company.

C. E. Hartay (A '40), formerly assistant to the general superintendent of distribution of the Dusquesne Light Company, Pittsburgh, Pa., has been appointed superintendent of operations, eastern division distribution department, of that company, He has been with the firm since 1925, holding various engineering positions.

H. B. Wolfe (A '26, F '45), formerly superintendent of electrical maintenance of the Duke Power Company, Charlotte, N. C., has been appointed operating superintendent for that firm.

R. G. Robbins (A '46) has been announced as the new divisional vice-president, eastern division, of Hubbard and Company, Pittsburgh, Pa. Robbins had been sales manager of that division for several years. Starting with the company in 1923, he had worked up through the advertising department to the sales division and his present office.

G. E. Garnhart (A '30, M '36) has been appointed director of the real estate and insurance division of the Westinghouse Electric Corporation. A graduate of Syracuse University, Garnhart joined the Westinghouse Corporation in 1927 as a student trainee, and since has held various positions in the engineering, purchasing, and accounting departments.

E. C. Day (A '43) has joined the AIEE headquarters staff, New York, N. Y., to prepare to succeed Charles S. Rich as secretary of the technical program committee. Mr. Day was formerly an electronics engineer with the pilotless plane division of the Fairchild Engine and Airplane Corporation of Farmingdale, N. Y.

E. H. Colpitts (A '11, F '12), director of the Engineering Foundation, New York, N. Y., will be the recipient of the Franklin Institute's 1948 Cresson Medal for his pioneering work leading to the development of practical systems of long distance communications, both by radio and wire. He was a member of the AIEE committees on Standards, 1916–18; telegraphy and telephony, 1919–24; research, 1933–37; Member-for-Life fund, 1944–47.

C. E. Ball (A '43), assistant district engineer Eastern Electricity Board, Luton District, England, has been appointed distribution engineer with the São Paulo Tramway, Light and Power Company, a subsidiary of the Brazilian Traction Light and Power Company.

B. W. Kendall (M '18, F '29) of the Bell Laboratories was elected first vice-president of the New York Electrical Society at its annual meeting, United Nations building, Lake Success, N. Y.

R. Jack West (A '36), former assistant chief engineer of Burlec. Ltd., Scarboro Junction, Ontario, Canada, has been appointed vice-president of the Wired Radio of Canada Limited, a subsidiary of Canadian Line Materials Limited of Toronto, Canada. He was in the special products division of the latter company following his graduation in 1935 from the faculty of applied science and engineering of the University of Toronto. Mr. West is a member of the Professional Engineers, Province of Ontario, Canada.

Florence Buckland (A '23, M '48) is the fourth woman to be honored with a full membership in the AIEE. She now is employed in the general engineering and consulting laboratory of the General Electric Company, Schenectady, N. Y., dealing with problems in heat transfer and fluid heat flow.

C. R. Marcum (A '43), Westinghouse Electric Corporation, East Pittsburgh, Pa., has been reappointed chairman of the papers and speakers subcommittee of the AIEE electronic power converter committee for 1948–49.

C. C. Herskind (A '26, M '40, F '48), electrical engineer, power rectifier department, General Electric Company, Schenectady, N. Y., has been reappointed chairman of the electronic converter circuits subcommittee of the AIEE electronic power converter committee for 1948–49.

OF CURRENT INTEREST

Mathematical Society Hears Series of Lectures at Meeting

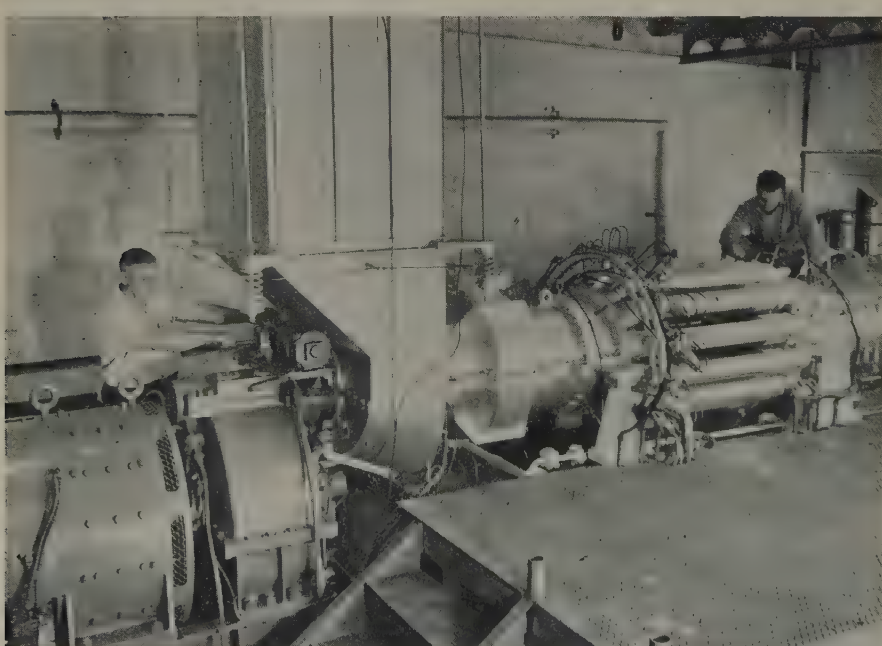
For many years mathematicians have been trying to find a satisfactory way of defining the area of a curved surface. This apparently easy task is full of hidden difficulties; for instance, if one defines area of a surface in a manner analogous to the definition of length of a curved line it turns out that every curved surface has infinite area—which is certainly an unsatisfactory state of affairs. Of the dozen or more definitions of area that have been proposed in the past 50 years, one given by the great mathematician Lebesgue in 1902 has attracted the most attention and has given the most reasonable answers to questions about surface area.

Lebesgue's concept of area was discussed in a talk given by Professor J. W. T. Youngs of Indiana University, at the joint summer meeting of the American Mathematical Society, the Mathematical Association of America, the Institute of Mathematical Statistics, and the Econometric Society. The meeting was held at Madison, Wis., from September 6 to 10, 1948. Professor Youngs was interested in the surprising fact that Lebesgue's definition, although stated in terms of analysis, leads to considerations which lie in the domain of topology, a branch of pure geometry. The results of his investigations along these lines were illustrated by a series of examples.

An important part of the meeting was a series of four Colloquium lectures, entitled "Representations of Groups and Rings," given by Professor Richard Brauer of the University of Toronto. "Group" and "ring" are the technical names for two types of algebraic systems which consist of abstract quantities having certain specified relations among themselves. The study of such systems usually arises as a by-product of some concrete problem and in turn may have applications to other problems. Thus group theory owed much of its inception to studies of crystal symmetry; 40 years later this theory, now highly developed, was found to be just the tool to use in certain phases of quantum mechanics. In studying the properties of an algebraic system one can work with the abstract quantities themselves or one can consider a more concrete system which "represents" in some way, the abstract one. Certain types of such representations have been found to be very useful in studying rings and fields. In his lectures Professor Brauer outlined the known facts about such representations, showed how they are related to other branches of algebra, and explained how they can be used to obtain additional knowledge of the structure of groups and rings.

In addition to these principal lectures there were nearly 100 short talks on a wide variety of topics in pure and applied mathematics, ranging from the computation of rocket trajectories to the theory of infinite-dimensional spaces.

Gas Turbine for Industry Service



Expected to be the first application of a mechanical drive combustion gas turbine in industry in the United States, the same 2,000-horsepower turbine which has completed more than a thousand hours of test operation at the Westinghouse Electric Corporation's Essington, Pa., plant is being prepared for shipment to the Mississippi River Fuel Corporation. It will go into service driving a compressor on their natural gas line between Monroe, La., and St. Louis, Mo.

AIEE Members Become IRE Fellows. The Institute of Radio Engineers has announced the election to the grade of Fellow of the following members of the AIEE: H. A. Affel (A '18, F '41), Bell Telephone Laboratories, New York, N. Y.; F. E. d'Humy (A '20, F '30), Western Union Telegraph Company, New York, N. Y.; F. W. Grover (A '21, M '30), Union College, Schenectady, N. Y.; E. A. Guillemin (A '24), Massachusetts Institute of Technology, Cambridge, Mass.; L. C. Holmes (A '31, M '43), Stromberg-Carlson Company, Rochester, N. Y.; J. K. Johnson (A '28, M '44), consulting engineer, New York, N. Y.; H. J. Reich (A '32, M '43), Yale University, New Haven, Conn. The grade of Fellow is a distinction, and appointment thereto by the IRE board of directors is made on the basis of eminence and distinguished service.

Lincoln Welding Foundation Announces Textbook Awards

The trustees of The James F. Lincoln Arc Welding Foundation have announced a joint award of $5,000 to Professor C. D. Williams of the University of Florida, Gainesville, Fla., and to Professor E. C. Harris of Fenn College, Cleveland, Ohio, for their coauthorship of a textbook manuscript in the foundation's Textbook Award Program. The program's jury of award selected their manuscript entitled, "Structural Design in Metals," as the best modern textbook manuscript in the structural engineering field. The Irwin-Farnham Publishing Company of Chicago, Ill., will publish the new textbook which will be ready for distribution soon after the first of the year.

Professor C. D. Williams is head professor of civil engineering at the University of Florida. He is a member of the International Association of Bridge and Structural Engineers, Society of Experimental Stress Analysis, American Concrete Institute, and other technical societies. He has been engaged in engineering practice and teaching for 27 years.

Professor Harris is chairman of the department of structural engineering at Fenn College. He is a graduate of Fenn and has

had a wide experience in structural engineering with the federal government and some of the leading structural engineering firms in the United States. He joined the faculty of Fenn in 1942. He is a member of the American Society for Engineering Education, American Welding Society, and the American Society for Testing Materials.

The James F. Lincoln Arc Welding Foundation was created in 1936 for the purpose of contributing to industrial progress by encouraging and stimulating the study of arc welding and its application. In furtherance of its aims the foundation sponsored a $20,000 Textbook Award Program to encourage authors in the preparation of textbooks on structural and machine design for the use of engineering undergraduates. Through the program the foundation is reducing the delay between process development in industry and the treatment of these new developments in textbooks.

OTS Publications. The Office of Technical Services, United States Department of Commerce, announces the publication of the following: "Technical Problems Affecting National Defense," 8 pages. A listing of national defense problems as released by the National Inventors Council, including such problems as conversion of light and heat into electric energy, construction of lightweight radio equipment, high-speed electronic telegraphic printer, and many others. List (No. 1948–1) is available free from the Department of Commerce, Washington 25, D. C.; "PB-86272, High-Voltage Long-distance Transmission," 66 pages, plus diagrams. A comprehensive review of the theory and practice of German high-voltage long-distance transmission and includes an account of experiments undertaken in replacing alternating with direct current on proposed 400-kv lines. Microfilm copy, $3.25; photostat, $10. Also obtainable "PB-11197, Comprehensive Survey of the German Power Industry" 427 pages. Microfilm, $4.50; photostat, $29. Both available from the Library of Congress, Photo-duplication division, Publication Board Project, Washington 25, D. C. All checks or money orders should be made payable to the Treasurer of the United States.

"Synchrotron" Developed at GE Research Laboratory

A 70-million-volt synchrotron, a type of atom smasher, is being built for Queens University, Kingston, Canada. Under construction in General Electric's general engineering and consulting laboratory, Schenectady, N. Y., the machine will be used by the Canadian institution for nuclear research.

The synchrotron will be modeled after a machine developed by the General Electric Research Laboratory for use in atomic research. The laboratory's machine is the largest of its type in operation in the world.

Newest among the "particle accelerators," as atom smashers are known to nuclear physicists, the synchrotron, like the betatron, accelerates electrons. Significant advantages in this new type will include the development of higher voltage machines. Basic feature of the synchrotron is the principle of "phase stabilization" it employs. This means that accelerating electric impulses occur at exactly the right time to boost electrons as they circulate in the machine's vacuum doughnut, or acceleration chamber. The tendency for automatic synchronization gives rise to the name "synchrotron."

Although this electronuclear device utilizes an electromagnet, the main acceleration is provided by an electrostatic field. When electrons have been accelerated by magnetic induction to an energy of 2,000,000 electron volts, and are traveling at 97 per cent of the speed of light, a radio-frequency oscillator turns on automatically. The oscillator is connected to a gap on the inside of the synchrotron doughnut, and circling electrons receive an increase in energy each time they go past. At a predetermined time the path of the electrons is altered slightly so that they strike a small piece of metal inside the doughnut, producing an X-ray beam. These X rays are many times more penetrating than those produced by conventional X-ray machines, or by radioactive substances such as radium. The machine will be used to conduct research with high-energy X rays. The synchrotron will be installed in a special underground chamber to protect personnel from harmful radiations, and will be operated from a remote-control station in a nearby building.

Survey Shows Increase in Electric Truck Use

Industry as a whole bought more than $2^1/_2$ times as many storage battery-powered industrial trucks in 1947 as the average annual purchases in 1936–39, recent studies by The Electric Industrial Truck Association show. In a report just issued, it is shown further that the number of firms using electric trucks also has risen sharply since 1944, with 34 per cent more users now than four years ago. The association's analysis of numbers of electric trucks in use today, as compared with 1944, shows a ten per cent increase, despite the fact that many over-age units were kept in service during the war and only recently retired.

Observers of industrial developments attribute this increased use of electric trucks to two major factors—the growing awareness among industrial executives of the advantages of machine-size unit-load handling of parts, materials, and products in cartons, crates, barrels, bags, boxes, bins, racks, bundles, rolls, strapped together or often merely loosely stacked or interlocked; and to the versatility of use, safety features, smooth and silent operation, and low maintenance requirements of battery-powered trucks.

Several industries showed gains considerably above the average. The textile industry bought nearly seven times as many electric trucks in 1947 as prewar and unclassified process industries took more than seven times prewar requirements. Manufacturers of machinery required $4^1/_2$ times 1936–39 purchases. The greatest spread in numbers of users among manufacturing industries, as indicated by 4-year gains reported by the association, was in the food industry with $2^1/_4$ times more users in 1948 than in 1944. A gain of 75 per cent was made in the rubber goods industry, 58 per cent in machinery, 52 per cent in chemical and allied products, 47 per cent for ceramics, 44 per cent for textiles, and 40 per cent for the paper industry during the same period.

AIME Secretary Resigns. After 18 years in the position, Doctor A. B. Parsons has resigned as secretary of the American Institute of Mining and Metallurgical Engineers. The resignation becomes effective February 1949, but Doctor Parsons will be on leave of absence until that time. E. H. Robie, Parsons' principal assistant during nearly all his tenure of office, will be acting secretary during the remainder of the year.

Stearns New Science Committee Head. Robert L. Stearns, president of the University of Colorado, has been named chairman of the newly formed Scientific and Synthetic Analysis Committee by Doctor Vannevar Bush, chairman of the Research and Development Board, National Military Establishment, Washington, D. C. This new committee will examine all aspects of military activity to ascertain where scientific methods can be utilized to improve exiting procedures. The committee, which held its first meeting in October, consists of representatives from each branch of the Armed Forces, and Luis de Florez, president of the de Florez Engineering Company, Inc., and L. K. Marshall, president of the Raytheon Manufacturing Company, as well as Chairman Stearns.

Columbia River Power Talk. With the nation's aluminum stockpile already in short supply, Bonneville and Grand Coulee Dams, furnishing power to produce about half the nation's output of primary aluminum, are of major significance to the growing economy and security of the United States. This statement was made at the American Society of Mechanical Engineer's fall meeting by Doctor Paul J. Raver, Bonneville Power Administrator. Begun to create jobs, he said, these dams were completed just in time to provide momentous contributions to the war effort by supplying power for aluminum production. Postwar expansion has drained the power supply dry and has created a need for electric power estimated at about 550,000 kw of power capacity now and a total of 750,000 kw by 1952. The inability to provide more power is not only limiting regional growth, it is restricting development of fabricating industries which need aluminum in ever-increasing quantities, Doctor Raver said.

Longstreth Medal Given. The 1948 Longstreth Medal of the Franklin Institute "for encouragement of invention, and in recognition of meritorious work in science and the industrial arts," has been given to Nicholas F. Arone of Upper Darby, Pa., and Edwin H. Brink of Laurel, Miss., for their development of phospho-asbestos, an inorganic

thermosetting compound. This new material, developed at the General Electric Company's switchgear division laboratory at Philadelphia, Pa., contributed greatly to the creation of an improved interruptor for power circuit breakers operating in air which will eliminate dangerous oil circuit breakers.

New Betatron Generates High-Voltage X Rays

A 50-million volt betatron to produce high-energy X rays that may have value in cancer treatment has been announced by the General Electric Research Laboratory. The new device, weighing about eight tons, is a compact version of the 135-ton hundred million-volt betatron which has been in use at the laboratory for several years in atomic research. Research shows that radiation of 50 million volts will penetrate into the body more deeply and effectively than those of lower voltage.

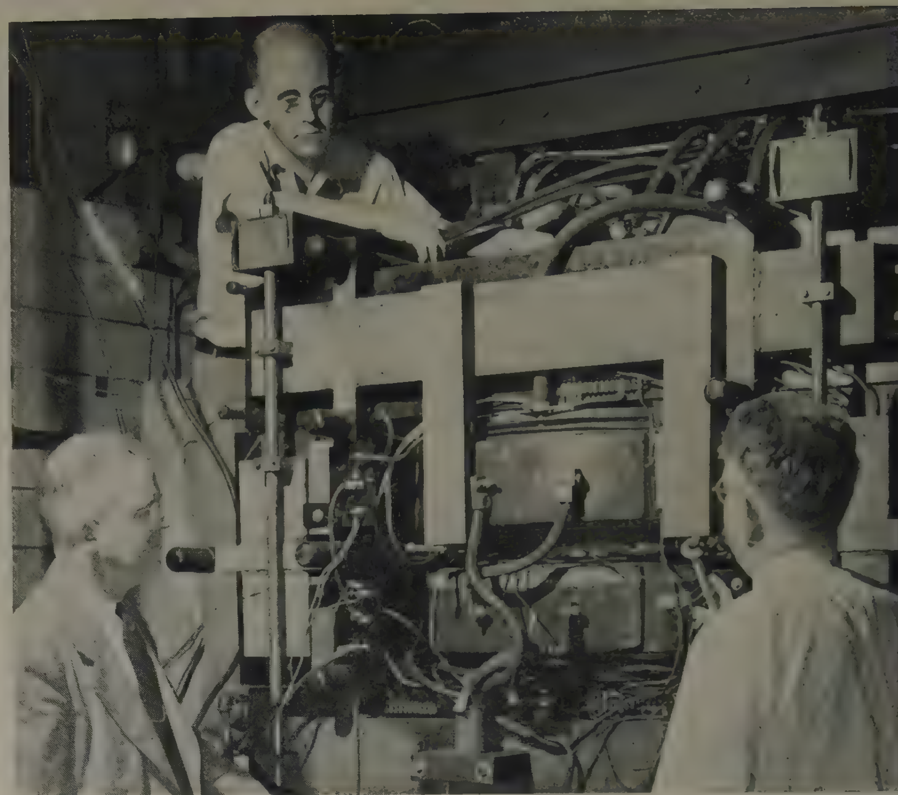
A machine of this size may be mounted on trunnions so the beam may be directed toward the patient at any desired angle, something hardly feasible with the 135-ton betatron. No medical experiments have been made with the 50,000,000-volt device and none are planned. However, the new betatron will be used in connection with a program to be conducted with the support of the Atomic Energy Commission by the biology department of Union College in Schenectady, N. Y., to study the effects of high-energy radiation on living organisms.

The betatron consists principally of a large electromagnet. In the heart of the device, between circular polefaces, is a doughnut-shaped vacuum tube. Electrons, emitted from a hot filament inside the tube, are whirled around thousands of times and are accelerated constantly while the magnetic field builds up. As the field reaches its maximum, the orbit of the whirling electrons is shifted and they hit a tungsten target which they missed on previous trips. This generates a beam of high-voltage X rays, and occurs at the rate of 60 times per second.

This is the fourth betatron built in the General Electric Research Laboratory. The first, of 20,000,000 volts, was loaned to the University of Illinois. Second was the 135-ton machine, and then came a 10,000,000-volt machine to produce penetrating X rays for industrial inspection. In addition, a second 50,000,000-volt betatron is being built for the National Bureau of Standards in Washington, D. C.

WSE Starts New Magazine. The Western Society of Engineers announces the combining of their *Journal* and *Bulletin* into a single magazine to be called *Midwest Engineer*, with an aim at broader editorial treatment and broader news coverage for the midwest area. To be published monthly, except during June, July, and August, it will contain both technical articles and stories of general interest not only for professional folk but for the public as well. With the first issue coming out in September 1948, the lead story will be a special article each month on some phase of engineering development and industrial progress.

Betatron for Medical Use Finished



Doctors E. E. Charlton (left), W. F. Westendorp (center), and F. R. Elder (right) examine the 50,000,000-volt betatron recently completed for medical use at the General Electric Research Laboratory. Doctor Charlton heads the laboratory's X-ray section.

General Brentnall Speaks to ASME Aviation Conference

An address by Brigadier General S. R. Brentnall, United States Air Forces, deputy director of research and development, Air Materiel Command, Wright Field, Ohio, featured the 1948 Aviation Conference of The American Society of Mechanical Engineers, held in Dayton, Ohio, Monday, September 20 and Tuesday, September 21, 1948. He spoke on "Design for Environment."

The annual meeting sponsored by the ASME aviation division, previously held in Los Angeles, Calif., was transferred this year to Dayton so that the engineers might inspect the facilities of Wright Field. The entire second day of the conference was given over to inspection tours of the power plant and aircraft equipment laboratories and to observance of flight test demonstrations of the latest types of aircraft at the Wright-Patterson Air Force Base, including newest American fighting craft.

Technical papers included the following: "Analysis of the Activities of Navigators during Three Arctic Missions," J. M. Christensen, research psychologist, aeronautical medical laboratory, Wright-Patterson Air Force Base; "Cockpit Design Problems of High-Altitude High-Speed Flight," J. E. Sullivan, director of air-borne equipment division, Bureau of Aeronautics, Washington, D. C.; "Turbojet Engine Controls," C. S. Cody, section engineer, aviation gas turbine division, Westinghouse Electric Corporation, Philadelphia, Pa. "Thrust Augmentation as Applied to the Turbojet Engine," Edward Woll, development engineer, aircraft gas turbine engineering division, General Electric Company, West Lynn, Mass.

Stanford's Atom Smasher Planned to Be World's Biggest

Stanford University physicists will build what is expected to be the world's most powerful atom smasher, an electron linear accelerator capable of hurling particles with a billion electron volts of energy. The development work, which will extend over a 3-year period, will be financed under contract with the Office of Naval Research.

Construction work is under way on a building to house the projected 160-foot accelerator which, it is said, will develop at least three times as much energy as the massive cyclotron at the University of California. The 400,000,000 electron volt output of this cyclotron is the greatest amount of energy that man has imparted so far to an atomic particle. A 12-foot "pilot model" of the accelerator, constructed more than a year ago under an Office of Naval Research contract, already has produced electrons of 6,000,000 electron volts.

By extending the length of the slender accelerator tube and by developing power sources 100 times as potent as those used in

radar, the Stanford staff hopes to do what to date scientists have only dreamed of accomplishing—bombarding the heart of the atom with a stream of billion-volt electrons. Achievement of this goal would open a whole new field of experimentation in elementary particle physics, and bring scientists much closer to an understanding of the fundamental nature of matter and how it is put together. It is impossible to predict what will happen over the horizon of atomic research, well into the billion-volt range, it was added, but many fascinating possibilities appear when enough voltage is available. Besides the study of existing matter, it may be possible actually to create protons and neutrons—the component parts of the atom nucleus.

The building, which is scheduled for completion by the end of January 1949, will be financed largely by university royalties from the Klystron (which was developed at Stanford in the late '30s) and a special building fund contributed by Sperry Gyroscope Company. The laboratory will be a one-story concrete structure with a steel frame, 86 feet wide by 300 feet long. The linear accelerator will be placed in the center of the building, flanked on each side by offices and shops. Elaborate precautions will be taken to guard against the dangers of atomic radiation. Concrete blocks several feet thick and lead sheets will shield the accelerator tube.

The laboratory building also will be the center for microwave research and graduate instruction at Stanford. It will contain offices for faculty members, research assistants and graduate students; shops for machining, plating, vacuum tube assembly, and radio assembly; a library; a drafting room; stock rooms; a conference room; and a classroom.

Civil Service Engineer Applications. The United States Civil Service Commission has announced that applications for the following positions will be accepted by the Executive Secretary, Board of Civil Service Examiners for the United States Department of Agriculture, Agricultural Research Center, Beltsville, Md.: rural electrification engineer (P-2 to P-4), $3,727 to $5,232 per year, with options in design and construction, generation and transmission, farm electrification, or wiring; home economist (electrical) P-3 (field) $4,479 per year.

Turbine Steam Pipes to Run Dull Red

The 100,000-kw turbine recently shipped by the Westinghouse Electric Corporation for installation at the Sewaren generating station of the Public Service Electric and Gas Company of New Jersey will operate at such high temperatures and pressures that the steam pipes feeding it will glow a dull red. Steam at 1,500 pounds pressure and 1,050 degrees Fahrenheit will feed the new 3,600-rpm tandem compound double flow machine. This is the first steam power plant to be constructed for operation under such conditions. While the highest temperature previously used in turbines is 1,000 degrees Fahrenheit, it is the last 50 degrees Fahrenheit that makes the job tougher.

To withstand operating in the dull red region, steam containers such as the throttle valves, steam chests, and other high-pressure parts of the turbine are constructed of 18–8 stainless steel. Fabrication of parts from this hard-to-work material has been a problem in itself. The importance of the 50-degree rise in temperature is in the fuel savings. For each 50-degree increase, the quantity of coal required to produce one kilowatt-hour of electric energy is decreased by about 1.4 per cent. In 1915 the output of all steam power plant turbines averaged only 525 kilowatt-hours per ton of coal burned. With further developments towards increased plant efficiency, the output of all steam power plants by 1945 was 1,550 kilowatt-hours per ton of coal burned. These figures include both old and modern plant equipment in service during the year mentioned. This new turbine will produce about 2,500 kilowatt-hours of electric energy from each ton of coal burned.

New Plastic Developed. Development of a new mineral-filled, quick-setting plastic material, designated as Plaskon alkyd molding compound, has been announced by the Plaskon division, Libbey-Owens-Ford Glass Company, Toledo, Ohio. Primarily an industrial plastic and offered as particularly suitable for electrical and mechanical applications, Plaskon alkyd has been field-tested for two years. First applications of the compound were on electric connectors, switch units, and similar parts. The compound is produced in granular form and is naturally brown, but can be produced in a range of colors. Most significant characteristic is its rapidity of cure, the molding process being measured in seconds. The new material also opens the way to less costly molding operations through the use of fast acting inexpensive presses. Plaskon alkyd differs from other thermosetting plastics in that it has unusual electrical characteristics.

Southwest IRE Conference in Dallas. For the first time in the southwest, engineers in radio and allied fields will attend one of the largest displays of technical talent and electronic equipment ever assembled in this area. The Southwestern Institute of Radio Engineers Conference will be held in Dallas, Tex., December 10 and 11, at the Baker Hotel. Papers of outstanding merit will be presented and manufacturers' exhibits of equipment will be displayed. Field trips to points of interest, including a television station in Fort Worth, have been arranged.

RMA-IRE Hold Fall Meeting Jointly. Various technical advances in both television and radio manufacturing will be discussed at the annual Rochester fall meeting of the Radio Manufacturers Association engineering department and the Institute of Radio Engineers on November 8, 9, and 10 at the Sheraton Hotel, Rochester, N. Y. The tentative program includes a number of technical papers on television and other industry developments and studies.

Welding Papers Awards Are Presented to Winners

Prize awards for the best papers on resistance welding topics submitted in the 1947–48 national contest were announced by a special jury of awards of the American Welding Society. All prizes were donated to the AWS by the Resistance Welder Manufacturers' Association. First RWMA prize winner in the industrial division of the contest was Frank G. Harkins, Solar Aircraft Company, San Diego, Calif., who was presented with $750 for his paper on "Spot Welding Schedules for Nickel and Nickel Alloys." "University source" division first prize went to W. F. Hess, W. D. Doty, and W. J. Childs, all of Rensselaer Polytechnic Institute, Troy, N. Y., for their paper "Heat Treatment of Spot Welds in Steel Plate." The $500 second prize money in the industrial division went to R. C. Jones, Taylor Winfield Corporation, Warren, Ohio, for his paper on "Resistance Welding of Crossed Wires," while C. E. Smith and R. H. Blair of the same company collaborated to win the $250 third prize with their paper on "Resistance Welding Characteristics of the Dry Disk Rectifier Welder." W. F. Hess and W. J. Childs of Rensselaer also were awarded second prize in the university division for their paper on "A Study of Projection Welding."

Symposium on High-Frequency Measurements. The subcommittee on high-frequency measurements of the instruments and measurements committee is planning jointly with the Institute of Radio Engineers and the National Bureau of Standards a 2-day symposium on high-frequency measurements to be held January 10–12, 1949, in Washington, D. C. Four sessions on the following topics are being planned:

1. Frequency measurements.
2. Power, voltage, current, attenuation measurements.
3. Impedance, dielectric, and magnetic measurements, millimeter techniques (optical-type gratings, artificial dielectrics using dispersed metals, special problems).
4. Noise, field intensity, antenna measurements.

The full program is scheduled for publication when it becomes available.

United States Forms Committee to Aid Liaison With UNESCO

The United States has formed a National Commission which will advise the government in matters relating to the United Nations Educational, Scientific, and Cultural Organization, and will serve as liaison with organizations, institutions, and individuals in matters pertaining to UNESCO activities.

The commission will be headed by Milton S. Eisenhower, president of the Kansas State College of Agriculture and Applied Science, and will be composed of 100 persons, 60 of whom will be from voluntary cooperating organizations. The remainder will be appointed from various federal and state governmental departments.

Science will have 12 members, 8 of them being representatives from the following organizations: American Philosophical Society, American Association for the Advancement of Science, American Chemical Society, American Society for Engineering Education, Association of American Medical

Colleges, National Academy of Science, National Research Council, and the Engineers Joint Council.

This last group is composed of the president, junior past president, and secretary of following engineering societies: AIEE, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, and American Society of Mechanical Engineers.

The UNESCO program is divided into six chapters, one of which is natural sciences. One of its major projects is the establishment of international engineering sciences organizations. A contract, made in October 1947 with the World Engineering Conference, started an international survey of existing engineering societies and institutions and is nearing completion. Accompanying special reports and this survey will pave the way for international co-operation in the engineering sciences, it is hoped.

S. E. Sheppard Dies; Was Photographic Expert

Doctor Samuel E. Sheppard, internationally known research chemist and scientist, and formerly with the Eastman Kodak Company, died at his home in Rochester, N. Y., September 29, 1948. He had been in retirement from the Kodak Research Laboratories since January 1948, after 35 years of service.

Born in Kent, England, in 1882, Doctor Sheppard began to specialize in photography while a student of chemistry at the University College of London. His thesis, "Investigations on the Theory of Photographic Processes," written and published in 1907 while he was working for his doctor of science degree, is a photographic classic to workers in the field. It was written in collaboration with Doctor C. E. K. Mees, Eastman Kodak vice-president, a lifelong friend and coworker of Doctor Sheppard.

Doctor Sheppard began working for the Kodak Company upon the organization of the Research Laboratories in 1913, and from 1924 on was assistant director of research. His investigations resulted in major discoveries, both in the field of photography and in related fields. He also published over 250 scientific papers as well as several books which covered every phase of his work.

Among Doctor Sheppard's awards were the William H. Nichols Medal from the American Chemical Society in 1930, and the Adekskiold Gold Medal of the Photographic Society of Stockholm, Sweden. He had also received the Progress, Hurter, and Driffield Medals of Royal Photographic Soc.

Among Doctor Sheppard's memberships were those in the American Chemical Society, the Society of Motion Picture Engineers, Optical Society of America, American Electrochemical Society, American Association for the Advancement of Science, American Standards Association, London Chemical Society, and the National Research Council. He was past president of the Society of Rheology.

Future Meetings of Other Societies

American Institute of Chemical Engineers. November 7–10, 1948, Hotel Pennsylvania, New York, N. Y.

American Mathematical Society. November 3–5, 1948, Birmingham, Ala.

American Oil Chemist's Society. Fall meeting, November 15–17, 1948, Pennsylvania Hotel, New York, N. Y.

American Society of Mechanical Engineers. November 28–December 3, 1948, Hotels Pennsylvania and New Yorker, New York, N. Y.

American Society of Refrigerating Engineers. 44th annual meeting, December 5–8, 1948, Washington, D. C.

American Society for Testing Materials. District meetings: November 4, 1948, St. Louis, Mo., at the Engineers Club; November 10, 1948, Philadelphia, Pa., at the Franklin Institute; November 16, 1948, Cleveland, Ohio, at the Cleveland Engineering Society; November 19, 1948, Worcester, Mass., (New England) at the Hotel Sheraton; November 29, 1948, Pittsburgh, Pa., at the Mellon Institute.

Material Handling Conference. November 8–9, 1948, Hotel Statler, Buffalo, N. Y.

National Electrical Manufacturers Association. November 8–13, 1948, Atlantic City, N. J.

National Electronics Conference. November 4–6, 1948, Edgewater Beach Hotel, Chicago, Ill.

National Exposition of Power and Mechanical Engineering. November 29–December 4, 1948, Grand Central Palace, New York, N. Y.

National Farm Electrification Conference. November 17–19, 1948, Congress Hotel, Chicago, Ill.

Society of Naval Architects and Marine Engineers. November 10–13, 1948, Waldorf-Astoria Hotel, New York, N. Y.

Southwestern Institute of Radio Engineers Conference. December 10–11, 1948. Baker Hotel, Dallas, Tex.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

"Atomic Energy"

To the Editor:

It has occurred to me that the engineering world is not very dignified concerning so-called "atomic energy." With the rapid advancement in electronics and physical chemistry and the nuclear physics it was a logical step to cause an atomic explosive. It has its parallel in the discovery of dynamite by Nobel. Dynamite was a great invention but it is as nothing to modern aviation gasoline. Calling nuclear fission "atomic energy" is a little premature. What will we call the energy we get someday when we have found a way to convert matter into energy.

Of course, man has stuck his prying scientific key into the heart of matter but just because the door blew off should not make him feel he is the master of his physical world. We are about as far from real atomic utilization as our forebears when they learned how to make fire were from the modern supersonic turbojet-engined plane. Let us tone down our superlatives. As engineers we should take the time to look backwards and review what we know of electronics and physical chemistry. Just because books on nuclear physics have been banned for seven years, a lot of us, especially the younger of us, have been deprived of the background which was rightfully ours. Security did necessitate certain restrictions. Uranium became a new philosopher's stone.

It would be foolish to suppress the large field of nuclear physics into a small esoteric sanctum of uranium behavior. Let us open the windows and let the free air and light into the pseudo-religious realm of electrochemistry. Being an engineer and not having the special training in electron mechanics I still feel that just as soon as the high priests of nuclear mechanics put their cards on the table we practical fellows will be able to utilize this 20th century "dynamite." Let us forget uranium and the fissionable elements and go back to all matter.

The sun seems to be doing a possible job with some of the lighter elements. It is also possible that the heavier elements do not exist in the sun. The energy problem was not solved chemically with dynamite. Neither is the energy problem solved atomically with fission. I hope the AIEE will take the modest stand and not go on record by making any statements which will look ridiculous 50 years from now. Engineers also must be philosophers and not be too proud of their accomplishments. The atomic bomb was a project conceived and designed in the conventional manner with its research, development, specifications, blueprints, and construction. It was a remarkable project and it will stand out as the greatest engineering feat of modern times.

Engineers naturally would release the power of the electron some day. Electrical engineers have been causing electrons to work ever since the discovery of electric energy. Some day they will cause electrons to behave in any desirable manner. Chemists have been operating on the fringe of electron mechanics since they started. Valence, endothermic and exothermic reactions have been electrons at work. Storage batteries and wet and dry cells have been the only link between chemistry and electricity in the past. The true nature of matter now widens the horizon of the electrical engineer. The future electrical engineer will have to be very conversant with the elements. The electromotive series will have a new significance. The need for higher, broader education in this field will be evident. Cur-

ricula will need an overhauling. The release of atomic energy will have such repercussion in our whole lives that we must be cautious. There are several discoveries involving electrons which could be worked on now which does not involve fission, for instance the direct conversion of heat into electricity. A device for stepping up or down of direct current, utilization of the earth's magnetism, broadcasting of electric energy.

Let us not put too much hope into our new found "dynamite." There is a long road to travel yet. Current literature on atomic energy would lead us to think that a new age is dawning. Aside from its frightful military consequences we cannot count on it too strongly to lessen our burdens within the next quarter century.

HARRY E. SPEARS (A '41)
(Electrical engineer, Baton Rouge, La.)

New Saturable Reactor Principle

To the Editor:

I should like to present the following idea for the consideration of other readers.

Figure 1 shows two magnetic cores intersecting at right angles. Core *A* carries a coil connected to an a-c source; coil *B* on core *B* is connected to a source of direct current. If the current in coil *B* now is increased until core *B* is saturated, what will be the behavior of the a-c flux at the intersection of the cores and what will be the effect on the impedance of the a-c coil? Also, what happens at values of d-c flux between zero and saturation value?

My own opinion is as follows: If core *B* is saturated then no further magnetization

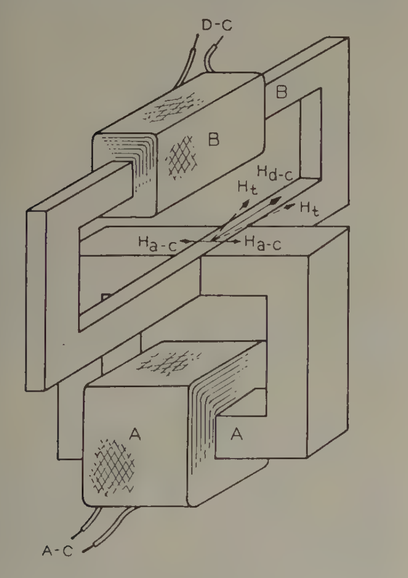


Figure 1

can take place in it in any direction; hence that portion of the magnetic material common to both flux paths will behave very much like an air gap as far as the alternating current is concerned. The a-c coil's impedance will be high. At intermediate steps of d-c flux the impedance of the a-c coil will vary between rather wide limits as in an ordinary saturable reactor, but the harmonic distortion characteristic of the ordinary saturable reactor will be absent, or nearly so.

If this idea is correct it seems that this principle might have practical application in saturable reactors, small voltage regulating transformers, and the like.

FRANK W. SMITH
(Tennessee Valley Authority, Chattanooga, Tenn.)

Use of Thevenin's Theorem

To the Editor:

It is quite surprising to learn how little instructors of electrical engineering make use of Thevenin's theorem as an aid to solution of problems. I wish to present here a rather interesting application of Thevenin's principles to a 3-phase problem usually given to electrical engineering students studying 3-phase systems for the first time. Consider the problem shown in Figure 1 which was given to electrical engineering students at the Georgia School of Technology when I was an instructor there.

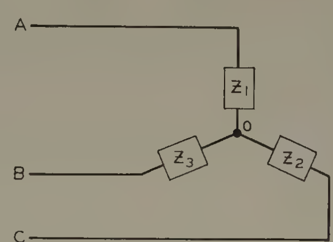


Figure 1

Given:

$E_{CA}=60+j75$
$E_{AB}=40-j100$
$E_{BC}=-100+j25$
$Z_1=5\underline{/53.2°}$
$Z_2=10\underline{/36.8°}$
$Z_3=13\underline{/-67.4°}$

Find:

I_B and V_{OA} in vector form.

For illustration, let us replace the applied 3-phase voltages with three single-phase generators and consider X_1 as the load in question. Therefore, the equivalent circuit shown in Figure 2 is obtained.

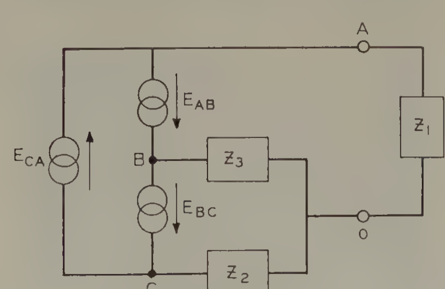


Figure 2

By the use of Thevenin's theorem, Figure 2 can be replaced by the circuit shown in Figure 3.

Z_{eq} and E_{eq} are obtained easily applying Thevenin's theorem. Removing Z_1 and short-circuiting the three generators in Figure 1, Z_{eq} is then the impedance measured between terminals $A-O$.

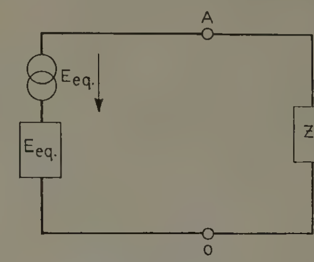


Figure 3

$$\therefore Z_{eq}=\frac{Z_2Z_3}{Z_2+Z_3}=\frac{(10\underline{/36.8°})(13\underline{/-67.4°})}{8+j6+5-j12}$$

$$Z_{eq}=\frac{130\underline{/-30.6}}{14.3\underline{/-24.8}}=9.09\underline{/-5.8°}$$

Removing Z_1 in Figure 2, the open circuit voltage measured between terminals $A-O$ will be equal to E_{eq}.

$$\therefore E_{eq}=E_{AB}+E_{BC}\frac{Z_3}{Z_2+Z_3}=40-j100+\frac{(-100+j25)13\underline{/-67.4°}}{8+j6+5-j12}$$

$$E_{eq}=40-j100+\frac{(103.2\underline{/166°})(13\underline{/-67.4°})}{14.3\underline{/-24.8}}$$

$$=40-j100+93.8\underline{/123.4°}$$

$$E_{eq}=40-j100-51.5+j78.5=-11.5-j21.5$$

$$E_{eq}=24.4\underline{/241.9°}$$

Having obtained E_{eq} and Z_{eq}, the voltage V_{AO} and current I_A now are obtained by use of Figure 3.

$$V_{AO}=E_{eq}\frac{Z_1}{Z_1+Z_{eq}}=\frac{(24.4\underline{/241.9°})(5\underline{/53.2°})}{3+j4+9.09\underline{/-5.8°}}$$

$$V_{AO}=\frac{122\underline{/295.1°}}{3+j4+9.04-j0.92}=\frac{122\underline{/295.1°}}{12.04+j3.08}$$

$$V_{AO}==\frac{122\underline{/295.1°}}{12.45\underline{/14.3°}}=9.8\underline{/280.8°}$$

$$V_{OA}=-V_{AO}=-9.8\underline{/280.8°}=9.8\underline{/100.8°}$$

$$\therefore I_A=\frac{V_{OA}}{Z_1}=\frac{9.8\underline{/100.8°}}{5\underline{/53.2°}}=1.96\underline{/47.6°}$$

In a similar manner V_{OB} and I_B are calculated.

$$V_{OB}=-V_{BO}=\frac{-E_{eq}^1Z_3}{Z_3+Z_{eq}^1}\quad I_B=\frac{V_{OB}}{Z_3}$$

where

$$E^1_{eq}=E_{BC}+E_{CA}\frac{Z_2}{Z_1+Z_2}=-100+j25+$$

$$(96\underline{/51.4})(10\underline{/36.8°})=90\underline{/127.6°}$$

$$Z_{eq}=\frac{Z_1Z_2}{Z_1+Z_2}=\frac{(5\underline{/53.2°})(10\underline{/36.8°})}{3+j4+8+j6}$$

$$=3.37\underline{/47.7°}$$

$$\therefore L_{OB}=\frac{(-90/\underline{127.6})(13/\underline{-67.4°})}{5-j12+2.31+j2.49}$$

$$\therefore I_B=\frac{97.5/\underline{292.7}}{13/\underline{-67.4}}=7.5/\underline{0.1°}$$

It easily is seen that the method employed is much shorter and avoids the use of simultaneous equations. The results are interesting in that we reduced a complex 3-phase problem to a simple, series, single-phase type.

The use of Thevenin's theorem is not restricted to electrical engineering problems. Other types of mechanical problems which were transformed to the electrical analogy were found easily solvable. There are probably many other applications of Thevenin's theorem.

This theorem should not be passed over lightly by instructors.

ISADORE COGAN (A '46)
(Instructor, electrical engineering department, Syracuse University, Syracuse, N. Y.)

Electrical Progress in Textiles

To the Editor:

The article by F. D. Snyder entitled, "Electrical Progress in the Textile Industry," (*EE, Sep '48, p 846*) is something of an innovation. It has seemed strange, with "textiles," one of our major and most important industries, and with such an unlimited field for design and application of new methods for electric drive and control, that so little has been published on the subject. Until a comparatively few years ago, the development of textile machinery was somewhat backward; looms, spinning frames, and other machinery used in the process being very little different in construction or operation than they were 50 years ago.

The first departures from this "rut," I believe, were made by loom manufacturers such as Crompton-Knowles and the Draper Manufacturing Company. They developed automatic individual motor-driven looms that would operate on worsted goods at 160 picks or more. The older looms had been picking at about 80 to 90 for years. In dyeing and finishing also, new developments, notably by Riggs and Lombard, Hunter Machine Company, and others, have been made. The old and inefficient belt-driven open wooden dye kettles and washers, which were operated with utter disregard of the quantities of steam and hot water used, have been replaced by enclosed models made of stainless steel and with dripproof and splashproof individual motor drive—all tending to efficiency and speed of operation. A notable example of this is the Riggs and Lombard continuous washer, which soaps, washes, and rinses the fabric in one continuous operation through a series of wash and rinse bowls with intermediate squeeze rolls—all synchronized and accurately timed for speed. Incidentally, the rather complicated control on this machine was designed by Mr. Snyder.

Now all this improved design of modern textile machinery has required special design of electric drive and control apparatus. In the case of individual motor drive for a loom, the duty cycle is such that special motor design is necessary, both for electrical and mechanical characteristics, the WR^2 or flywheel effect being an important factor. The same is true for individual motor drive for mule spinning frames. General purpose motors cannot be applied to such as these and many other machines used by the textile industry although many textile engineers do not yet realize that the day of applying a 10-horsepower motor to a 10-horsepower job long has passed, that the load cycle must be studied carefully in each case and special motors applied where necessary—if a maximum of efficiency in power and production is to be reached. More articles, by such men as Mr. Snyder, would help a lot. And God knows textiles need it.

BERNARD SCOTT (M '25)
(Lieutenant, United States Veterans Administration Hospital, Bath, N. Y.)

Capacitance Effects

To the Editor:

In the August 1948 issue of *ELECTRICAL ENGINEERING* (*p 833*), Professor W. B. Boast takes issue with me about the choice of units used in the article dealing with the capacitance effect of a conductor in a magnetic field, appearing in the August 1947 issue of *ELECTRICAL ENGINEERING*, pages 784–6.

Professor Boast's letter might give the impression that the results obtained with the formulas given in the original article are incorrect. If some of the readers have used the formulas and have become apprehensive about the correctness of their results, they may rest assured that equation 19, as well as the final expression in the foot-pound system, yield correct results if W is introduced as the weight of the armature in kilograms, or in pounds respectively. There is no trickiness or hidden meaning in the term "weight"; by it is meant the figure which will be indicated when the armature is placed on an ordinary butcher scale or a platform scale. In continental Europe such scales are calibrated in kilograms, while in Great Britain and the United States they are calibrated in pounds. (See, "Is It Weight or Mass?" by Walther Richter, Allis-Chalmers, *Electrical Review*, June 1948, page 31, reprints on request.)

In his recently published book, "The 14 Systems of Units," (O.S.C. Cooperative Association, Corvallis, Oreg., 1948) Professor W. M. Varner states in the preface: "Adoption in 1947 by the International Committee on Weights and Measures of Length, Mass, Time, and Permeability of Vacuous Space, as fundamental quantities has brought the number of systems in use to 14—six in mechanics and eight in electricity." Adoption of a new system may put the stamp of obsolescence on the previously employed systems, but it cannot brand them as more incorrect or illogical than they were before the adoption of the new system. Professor Boast tries to show that I have used the *MKS* system but have committed inconsistencies in its application; when he refers to the *MKS* system, he evidently has the so-called Giorgi system in mind, which officially was adopted by the International Electrotechnical Commission meeting at Scheveningen, Brussels, in June 1935, this action becoming effective in January 1940. In this system the meter, kilogram, and second, are the basic units of length, mass, and time. (See "MKS Units and Dimensions," by Jauncey and Langsdorf, The MacMillan Company, New York, N. Y., 1940.)

Professor Varner, in the afore-mentioned preface, continues as follows: "This multiplicity of systems has made necessary a careful analysis of the basic physical quantities and of the equations that express their interdependence." Such an analysis would have shown Professor Boast, that, out of the six possible mechanical systems, I was *not* using the *MKS* system, but the "technical" metric system, as was explicitly stated on the bottom of page 784.

The overwhelming majority of engineers have been trained in, and are using, the so-called "technical," sometimes also called "gravitational" systems (see: Eshbach, "Handbook of Engineering Fundamentals," section 3–14). In these systems the kilogram and the pound are units of force, and not of mass. I agree with Professor Boast that tying the definition of force to gravity is rather unhappy, and I hope, with him, that 50 years from how the word kilogram will only mean mass, forces being expressed in newtons; however, my article was not supposed to be an educational crusade for the use of a system of units which just recently had received formal recognition, and for this reason, the two gravitational systems, with which the majority of engineers are entirely familiar, were employed. And to make doubly sure what was meant by the term, "technical metric system," it was stated in the article that in this system the kilogram is the unit of force. One more reason for using this system is the fact that it is the exact counterpart, in metric units, of the English foot-pound system, as used by engineers in the United States. The latter is of course also a gravitational system, the unit of force being the force with which gravity pulls, at a certain specified spot on the surface of the earth, on a certain amount of material, the pound-body, preserved in London. When an American or British engineer talks of a pressure of 100 pounds per square inch, or states, that a certain spring, when compressed one inch, reacts with 25 pounds, the term "pound" means a force, pure and simple; on the way home, he may stop at the corner store and buy five pounds of sugar in which case he is of course more interested in obtaining a certain amount of substance. However, when he asks for a weight of five pounds of sugar he actually means: "Give me an amount of sugar on which gravity pulls with five units of force."

In the same way the European engineer gives a steam pressure in kilograms per square centimeter or the force exerted by a spring in kilograms. In the technical metric system, (not in the *MKS* (Giorgi) system), the kilogram is therefore the unit of force, and not of mass, as Professor Boast believes it should be. It is the force with which gravity pulls, at a certain spot on the surface of the earth, on a piece of material, called the kilogram body, preserved in Paris.

With the clarifying statement that in the technical metric system the kilogram is the unit of force, and not of mass, the objections of Professor Boast disappear. For instance, he states, "One cannot divide the weight of the body in Richter's kilograms by 9.81 to obtain the mass of the body as his equation 11 states." Naturally, if a system is used in which the kilogram is the unit of mass,

such a division by the value of gravitational acceleration would be senseless and incorrect. But in a system, in which the kilogram is the unit of force, the weight of the body in kilograms (that is, the force with which gravity acts on the body) not only may be, but must be, divided by an acceleration, to obtain its mass; if for no other reason, this step is necessary so as to have the dimensions on the two sides of the equation the same (mass = force/acceleration). Professor Boast then continues: "If so, may I ask for the name of the unit one thus would obtain?" Before answering this question, let me pose the following problem: Given an automobile, the weight of which is given on the registration card as 3,217 pounds; assume the car to be standing on a perfectly level surface, and assume that friction is negligible. With what force must the car be pushed, if it is to accelerate with two square feet per second?[2] If this problem is presented to an engineer, he of course will make use of the formula: force = mass × acceleration. The mass of the automobile he finds by dividing the weight by 32.16, obtaining a value of 100. The car has therefore a mass of 100, and in order to accelerate it with two square feet per second[2] we must push with 200 pounds. But what is the name of these 100 mass units, which the car possesses? Perhaps Professor Boast's experiences differ from mine, but very few of my mechanical engineering friends, to whom I addressed this question, come up with the right answer: "The car has a mass of 100 slugs." Most of them simply state that the car has 100 units of mass. In the technical metric system the situation is very similar. The unit of mass does not have any name, although "metric slug" has been suggested (see Marks, "Mechanical Engineers' Handbook," fourth edition, page 73).

When Professor Boast states that the meter kilogram is not a proper unit for energy or work, he is correct, when he is thinking of the *MKS* system, but not, when the technical metric system is employed. Table 42, section 1–140 of Eshbach, "Handbook of Engineering Fundamentals," gives the conversion factors between meter kilograms and other units of energy. Similarly, equation 17 on page 785 of the original article is correct, if T is given in meter kilograms, but the deletion of the factor 9.81 as suggested by Professor Boast is of course necessary, if the torque is inserted in meter-newtons.

I could not help being somewhat amused about the suggestion that the symbol G in Rüdenberg's formula should be interpreted as mass, not as weight, as the "W" in WR^2 implies. It so happens, that the symbol G in the German formula stands for "gewicht," which means "weight" in English. In the German formula the weight of the armature in kilograms therefore must be introduced, just as in the term WR^2 in the British system W stands for the weight of the armature in pounds.

There is consequently nothing illogical in my checks between the technical metric system (which is entirely different from the *MKS* system, which Professor Boast has in mind) and the English system. In the technical metric system, W (or G) does not stand for mass, but for weight, that is, the force exerted on the body by gravity, in kilograms. In the English foot-pound system, W also stands for weight, that is, the force of gravity in pounds. In both systems the mass of a body is obtained by dividing its weight by the acceleration of gravity.

In closing, it may be of interest to point out, that the *MKS* system (or Giorgi system), in which the kilogram represents the unit of mass, and the newton represents the unit of force (a system which Professor Boast and I both hope will be adopted generally by engineers sometime in the future) has a counterpart in an English system, in which the pound is the unit of mass, and where the unit of force is the poundal. But since the poundal turns out as only approximately one-half ounce (weight), that is, a unit of force approximately 32 times smaller than what British and American engineers are used to now, it seems hardly probable that this system will ever be adopted generally.

WALTHER RICHTER (F '42)
(Consulting electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee 1, Wis.)

To the Editor:

Mr. Richter and I are in agreement, I believe, upon the desirability of making the publication *ELECTRICAL ENGINEERING* as useful as possible to the advancement of the electrical engineering profession. The whole thesis of my letter to the editor in the August 1948 issue was stated in the first paragraph of that letter.

My thesis was *not* that the conclusions contained in Mr. Richter's paper were erroneous when interpreted in light of the definition of terms in that article, but that an unwise choice of units had been made.

Because the kilogram has received official sanction as a unit of mass, then, I believe, we should use it as such in technical publications.

From Mr. Richter's other publications on the subject of units, as well as from several statements made in his reply to my earlier letter, I would infer that he would favor unification in this respect at least at some time in the future (perhaps 50 years from now). I would agree with these possibilities of the future of course, but I would come also to the present and state that "I hope that from this moment and henceforth the word kilogram will mean mass, forces being expressed in newtons."

W. B. BOAST (M '43)
(Professor of electrical engineering, Iowa State College, Ames, Iowa)

Credit Where Due

To the Editor:

I heartily concur in the sentiment of Mr. G. G. Waite, where, in the September issue of *ELECTRICAL ENGINEERING* (*p 932*), he comments upon the failure of the author of "A New Watt-hour Meter" (*EE, Jul '48, pp 627–9*) to give credit where credit is due in his treatment of the magnetic suspension meter. This principle, as Mr. Waite implies, was well-known to the meter men of a generation ago; and, while the invention was obviously premature and its application failed to attain the peak of success which apparently characterizes the new meter, yet the basic idea was there, and certainly should have received attention in any article attempting to treat the meter from an engineering point of view. As a matter of interest, the principle is disclosed fully in United States Patent 588,666, granted to W. Stanley and F. Darlington, August 24, 1897. This patent is among those listed in the AIEE report "Progress in the Art of Metering Electric Energy" (December 1941), which report also shows a cut of the old Stanley meter.

It is unfortunate that commercialism tends to bias the writers of supposedly technological articles into a false perspective wherein pioneer work not identifiable with their own associates is belittled or suppressed. I believe that the reviewers of such articles should be alert to see that this tendency does not become dominant, and to encourage writers of engineering articles dealing with important advances in the art to provide adequate background in the nature of direct citations or bibliographical references.

PERRY A. BORDEN (F'44)
(Patent engineer, The Bristol Company, Waterbury, Conn.)

Dimensions of Resistivity

To the Editor:

The correct dimensions of resistivity are resistance times length (for example, ohms times centimeter or ohms times inches). This simple and obvious fact apparently has been almost forgotten. If a proof is required, as indeed it seems to be, let R be the d-c resistance of a current path of length L, area A, and resistivity ρ. Then, since

$$R = (\rho L)/A$$

$$\rho = R\frac{A}{L}$$

or dimensionally

$$\text{Resistivity} = \text{resistance times } \frac{\text{area}}{\text{length}} = \text{resistance times length}$$

The practice of expressing resistivity in "ohm-cm^3" originated from writing out "ohms for a centimeter cube." The contraction is particularly misleading as a hyphen frequently is used in place of the multiplication sign in dimensional expressions. Thus "ohm-cm^3" seems to mean "ohm × cm^3" or, where the multiplication sign is understood, "ohm cm^3." If one attempts to convert one "ohm cm^3" to the dimensional system employing inches rather than centimeters, he obtains

$$1 \text{ ohm cm}^3 = 1 \text{ ohm cm}^3 \times (1 \text{ inch}/2.54 \text{ cm})^3 = 0.061 \text{ ohm inch}^3$$

This is numerically wrong. The correct conversion, which only can be obtained by using the correct dimensional formula for resistivity, is

$$1 \text{ ohm cm} = 1 \text{ ohm cm} \times (1 \text{ inch}/2.54 \text{ cm}) = 0.394 \text{ ohm inch}$$

While many competent electrical engineers have used the form "ohm-cm^3" in the past, the writer believes that this practice should be discouraged and that the AIEE should insist on correct dimensional expressions for all physical quantities in the future.

J. W WILLIAMSON (A '43)
(Development engineer, Tocco Division, The Ohio Crankshaft Company, Cleveland, Ohio)

English Teachers for Engineers

To the Editor:

Professor Muir (*EE, Jul '48, pp 724–5*) has attacked an article, written by informed men, on the teaching of English to engineering students. The professor is right about "communications"; the primary need is to change the attitude of the teachers, not the name of the course. Yet his major contentions are contrary to experience.

Over the years I have heard various criticisms of the editors of technical writings who have been trained only academically. An example is: "If it sounds right, he's satisfied. He doesn't care what it means." Professor Muir cannot evaluate the justice of this criticism, because he has not the necessary knowledge of engineering. For the same reason his own sampling of published engineering articles will not tell him why those writings are acceptable to engineers.

Some of us object to the substitution of form for substance. Twenty centuries ago a great teacher expressed the same objection.

A sentence from Professor Muir's letter reads: "This aim is to give instruction in the writing of clear, accurate, logical expository English prose." This sentence demands that the vehicle be clear and accurate, but does not give a syllable to clarity and accuracy of thought. When the truck is spic and span, why bother with its load?

If the professor intended his sentence to mean something else, where is its clearness?

The sentence does not mention conciseness.

Most engineers write for themselves alone, without a thought of the audience. Professor Muir's letter ignores this vital error.

Courses in journalism, for instance, stress simple words and sentences. The instructors do not even mention any other style, as far as I know. An engineering author should have at least two styles, one for a technical audience and a different one for a nontechnical audience. These two are the minimum; he should also be able, for example, to write both for high-school students and for well educated but nontechnical adults, such as the directors of the company.

Professor Muir evidently is teaching essentially as he was taught. That product of inbreeding is the basic fault in the usual attempts to teach English to engineers.

A certain young instructor, in handling an advanced course in English, teaches principles and their application. His method is like teaching the principles of alternating currents, and then solving by those principles whatever problems turn up in the day's work.

The tradition-following colleagues of this young man require their students to memorize certain definitions, and then to memorize selected examples. That method is like memorizing a few definitions in alternating currents and then memorizing specified problems. It develops memory. The younger man's method, which accords with good engineering practice, develops reason.

The first requirement for clear and accurate writing is clear and accurate thinking. Another requisite is a knowledge of the subject. Experience long has shown that minor variations in the traditional method of teaching English are not enough for engineers (*EE, Jul '47, p 740*).

HENRY HENDRICKS KETCHAM (M '23)

(Box 221, Piqua, Ohio)

Electrical Essays

To the Editor:

A number of letters to the editor concerning electrical essays which I have written, have appeared, and call for some comment from me.

Orientation of Diamagnetic Bar, January 1948, page 58. I want to thank B. Litman for the valuable contribution in his interesting letter in the May 1948 issue (*p 509*). It is remarkable that most American textbooks give the incorrect answer to this question. A correspondent writes me that this is not the case for European textbooks.

The origin of this widespread error is undoubtedly, as Litman points out, the report of Faraday that in his experiments he found a bismuth bar setting itself perpendicularly to the magnetic field. Faraday's field was not uniform.

I have suspected that an iron bar might also set itself transversely in a magnetic field if it had the appropriate kind of nonuniformity. I am glad to have Mr. Litman confirm this expectation.

Electrostatic Line of Force, January 1948, page 58 (reply). This essay, which indicated that a line of electric force in an electrostatic field may meet the smooth surface of a conductor other than perpendicularly, aroused a rather large number of somewhat violent protests. I have already replied to some of them in the August 1948 issue (*p 829*).

In the May 1948 issue (*pp 509–10*), T. W. Mouat and Martin Graham join the distinguished throng who say that I am wrong in my contention. However, I still obstinately insist that in my Figure 1, *ELECTRICAL ENGINEERING*, August 1948, page 829, the line *PA* is a line of force, and it is obvious that it is not perpendicular to the conducting surface.

Incidentally, I have no idea of how a massless charged particle will move if placed in an electric field, and so Mr. Graham's definition of a line of force as the path of such a particle is not of much use to me.

A God Has Fun, February 1948, page 187. James Moran, in the August issue, page 818 gives a very excellent mathematical proof that the God was right in expecting that man would not be able, by any experiment, to detect the adulteration of electric charge by a fixed proportion of magnetic charge. I want to thank him for this. I agree with him that, therefore, the question as to whether the electron is or is not magnetically adulterated in fixed proportion, is meaningless.

Which Source Feeds Which Load, April 1948, page 337. I cannot agree with William A. Tripp, August 1948 issue, page 828, that because the Poynting vector of the radio engineer, and the VI formula of the power engineer give opposite answers to the question asked in the essay, there is an "unhealthy situation in electrical theory." I think the diversity in the answers to the question asked in the essay is only a natural consequence of the lack of uniqueness in the concept of energy flow. All that it is possible for us to observe is the transformations of electric energy, into other forms, and these transformations are only the divergence of the vector electric energy flow. Since a vector field is not uniquely determined by its divergence, it follows that electric energy flow cannot be uniquely determined by any observed phenomena. It also follows that there is an infinity of possible postulated electric energy flows, all equally valid and "true" in the sense that they all have the same divergence, and therefore all correspond equally well to observable phenomena. The radio engineer and the power engineer happen to each respectively use a different, but equally valid energy flow postulate.

The question asked in the essay is a meaningless one. Although it also satisfies a conservation law, energy, unlike matter, does not have a continuing identity in space-time. Therefore, the question asked in the essay, which implies for energy such a continuing identity in space-time, has no absolute meaning. It has a meaning only relative to some postulated electric energy flow. The radio engineer of the essay would deny that the test described by Mr. Roberts (*EE, Aug 48, p 829*) proves that the source X_1 feeds the load R_2 before Mr. Roberts removes the source X_2 from the circuit. His Poynting vector tells him otherwise. After X_2 is removed, then the Poynting vector will say that X_1 feeds R_2, but before the removal of X_2 the Poynting vector says that X_1 feeds R_1. The fact that a switching operation on a system changes the distribution of power consumed in loads does not permit the proof that one proper energy flow postulate is more valid than another.

Suppose in the diagram of the essay, at the point B, a switch is introduced, connecting two points of the adjacent conductors which are at precisely the same potential, so that when closed, the switch carries no current. Then such a switch, either closed or open, will not change the conclusions of either the radio engineer or the power engineer as to the flow of energy to the loads when both sources are connected. However, if Mr. Roberts will make his test of removing the source X_2 with the switch closed, he will find the load R_1 continuing to be warm.

J. SLEPIAN (F '27)

(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

The Engineer's Part

To the Editor:

From time to time some very excellent articles concerning the status of the engineer have appeared in *ELECTRICAL ENGINEERING*. In the August issue, the article, "The Engineer's Part," by Harvey N. Davis (*pp 727–33*), does a particularly fine job of pointing out the value of engineering. It seems to me a pity that these articles must appear in a technical publication the majority of whose readers are engineers and of course already convinced of the value of the engineering profession.

The National Society of Registered Professional Engineers also is interested in improving the status of engineers and the recognition which they receive, but here again the articles are published in their magazine which is read almost exclusively by engineers. It seems to me that a serious effort should be made to bring such articles and the facts in them to the attention of other groups whom it is vital to sell on the idea that engineering is important. I do not have any specific suggestions to offer, but I think that this is something which the AIEE might do well to study. If we really wish to advance the recognition of engineers, we should do our preaching to groups outside of the engineering profession and particularly to management groups.

I was interested very much in the statement in Mr. Davis' article to the effect that in New York and other states no one legally may call himself an engineer unless he has been licensed after two examinations in one of which the theory of structures plays a considerable part. I always have been very much interested in the registration of engineers and at present am serving on a committee of the Wisconsin Society of Registered Professional Engineers, which committee is working on revision of the state registration law. In connection with this work, the registration laws of many states have been studied and there has been personal discussion with many engineers. It is evident that a very high percentage of the interest in registration comes from engineers who are interested in the construction of buildings. In fact, it is sometimes hard for these men to realize that there is any other kind of engineering. I think that the AIEE and other large engineering societies should keep a very watchful eye on the registration laws or we may find ourselves in the position of being unable to call ourselves engineers unless we are the type of engineer who is working on building construction.

P. B. HARWOOD (F '42)

Vice-president in charge of engineering, Cutler-Hammer, Inc., Milwaukee, Wis.)

Test for Synchronous Reactance

To the Editor:

I wish to discuss the article, "Modified Slip Test for Experimental Study of Synchronous Reactance," by Henry B. Hansteen which was published in the September 1948 issue of *ELECTRICAL ENGINEERING* (*pp 890–2*).

In our laboratory at Purdue University we have a coupled set of 220-volt synchronous machines, one with a stator frame that can be shifted, that apparently are identical to those used in the test described in the article.

We ran one machine as a synchronous motor to drive the other. With the field circuit of the second machine open we applied 115 volts, three phase, to its stator terminals. Then the stator frame was shifted until first a minimum current of 18 amperes and later a maximum current of 28.5 amperes were obtained. The voltage regulation of the source was sufficiently low that there was a negligible change in voltage with change of currents. From these values the corresponding value of the direct-axis reactance was 3.69 ohms and that of the quadrature-axis was 2.33 ohms. These values check well with the values of 3.6 and 2.4 ohms as given for rated current of 39.5 amperes in the article.

Then we increased to 230 volts the voltage applied to the machine under test and found the reactances had decreased to 3.43 and 1.78 ohms, respectively. These results showed that increased saturation had decreased the reactances.

By belting a d-c generator to the coupled set the synchronous machine having a stationary frame could be loaded as a synchronous motor. With this motor running idle the field of the other synchronous machine was excited until its line voltage was equal to that of the supply. Then one terminal of the machine stator was connected to one line of the supply. Next an a-c voltmeter was connected between a second stator terminal of the machine and a second line of the supply. Thus was formed a single-phase synchronizing arrangement in which the voltmeter was the indicating device.

The frame of the one machine then was shifted until the voltmeter read zero. Then when load was applied to the d-c generator the change in the torque angle of the synchronous motor caused a reading to occur on the voltmeter.

The supply voltage, the a-c generator voltage, and the voltmeter voltage form an isosceles triangle that can be solved readily for the torque angle, since it is the angle between the first two of these voltages. With the field current of the synchronous motor kept constant at the value required to produce unity power factor at no load it was found that the full-load torque angle was 25 degrees.

The latter arrangement is useful also for measuring the pull-out torque angle of a synchronous motor in that the voltmeter reading can be taken just as the motor pulls out of step.

GEORGE V. MUELLER (M '35)

Professor of electrical engineering, Purdue University, Lafayette, Ind.)

Safety in Aircraft

To the Editor:

I read T. B. Holliday's article on "Safety and Aircraft Electric Equipment," (*EE, Sep '48, pp 901–04*) with great interest because of some near-accidents and equipment failures which occurred recently in my personal experience. What I looked for in the article unfortunately was not there. Two matters, in my mind of extreme importance to the maintenance of safe flight, get by with little mention by Mr. Holliday.

The first concerns itself with the generally accepted rule in airframe design that multiple or simultaneous failures (of either the same or completely different types) are generally not to be considered in designing for failures. This undoubtedly has some merit, in that it limits the cascading of emergency installations ad infinitum, such as a sixth emergency equipment item to be used only when five others have failed. One emergency or standby system or equipment item is the general rule for maintenance of important functions, and in some rare instances, even more are supplied. Yet in the very recent past experience in the service of a large aircraft undergoing flight testing, three situations have occurred, resulting in serious curtailment of facilities necessary for flight, and in each situation, from three to four separate and independent failures occurred simultaneously or in rapid and overlapping progression.

One such situation involved the failure in rapid succession of three separate sources of primary 3-phase a-c power, involving two 37.5-kva auxiliary power units and a standby 1-kva inverter. The causes of failure are interesting in the light of their total dissimilarity and close timing. One auxiliary power unit blew its fuse (lost excitation and all controls), the other broke a cylinder wall, and the standby inverter stopped because of operation of its thermal protector resulting from unusually high ambient temperature.

An interesting development of this situation was that the procedure for manual operation of a fourth single-phase inverter for certain very important engine instruments and emergency fire shutoff valve motors was forgotten by the thoroughly trained flight test personnel in the stress of the emergency, presumably because there never before had been any necessity to use it in almost two years of flying. However, it was indeed fortunate that four sources of a-c power were made available for this flight test airplane, and that the flight engineer eventually discovered how to use it.

From these experiences, I derive the following conclusions:

1. That triple and quadruple failures do exist simultaneously, and where vital, must be designed for.

2. That little used standby or emergency facilities should be automatic if at all practicable.

3. That the malfunction of such little used standby or emergency equipment be readily apparent to the proper crew member by appropriate automatic signalling devices.

The second matter which Mr. Holliday fails to mention is the problem of personnel safety as applied to the newer high-voltage aircraft electric systems of 120 volts direct current and 120–208 volts alternating current, especially with regard to crew activity in fighting smoke or fire in flight caused by an electrical failure.

Large aircraft using such high-voltage systems lend themselves well to the use of sectionalized feeders and load center distribution of power. A desirable and (to me) necessary adjunct of this design is the inclusion of contactor disconnects for killing all power to a particular section of bus or to a load center to protect personnel from high-voltage shock and burns in fighting localized electric fires and smoke. The previously accepted practice of using the electric master switch to kill all power throughout the airplane is no longer good where so many important instruments, engine controls, flight controls, fire emergency controls, and hydraulic system controls are remotely operated electrically.

MORTON H. ADOLPHE (M '47)

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NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

FREQUENCY ANALYSIS, MODULATION AND NOISE. By S. Goldman. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 434 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $6. Emphasizing physical principles and practical applications, this book covers the subjects of Fourier series and Fourier integral analysis, the theory of modulation, and the theory of random noise. The prerequisite training is a knowledge of calculus and a good general knowledge of radio engineering. A feature is the large number of charts and figures illustrating the results derived.

MECHANIZATION TAKES COMMAND, A CONTRIBUTION TO ANONYMOUS HISTORY. By S. Giedion. Oxford University Press, New York, N. Y., 1948. 743 pages, illustrations, diagrams, tables, 10 by 6¾ inches, cloth, $12.50. In this book the author pioneers in an attempt to explore our modern way of life. Taking no stand either for or against mechanization as such, he traces the manner in which it has come to pervade the pattern of our life, from the egg-beater and vacuum cleaner to scientific management and the most notable works of art. The author is concerned with both the details of the technique of mechanization and with the roots of mechanization in the human mind. Two pivotal types of questions are explored: the first group is concerned with what happens when mechanization meets organic nature in the form of soil, food, growth, and so forth; the second set deals with mechanization and its relation to our intimate human surroundings.

MICROWAVE TRANSMISSION CIRCUITS. (Massachusetts Institute of Technology Radiation Laboratory Series, volume 9.) Edited by G. L. Ragan. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 725 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $8.50. The problems of the transmission of power from one place to another at microwave frequencies are discussed fully from a practical point of view. The elementary theory of operation and the complete design procedure are described for many essential components of transmission lines. Consideration of power-handling capacity, loss, and convenience of use are discussed in relation to the best choice of the type of transmission line for a given application. Methods for extending the frequency range for good operation also are treated.

MODERN OPERATIONAL CALCULUS WITH APPLICATIONS IN TECHNICAL MATHEMATICS. By N. W. McLachlan. Macmillan Company, New York, N. Y., and London, England, 1948. 218 pages, diagrams, tables, 8½ by 5½ inches, cloth, $5. Written for postgraduate engineers and technologists, this book is an introduction to operational calculus based on the Laplace transform. Various theorems are used to solve ordinary and partial linear differential equations, to evaluate difficult integrals, to obtain mathematical relationships and expansions, and to derive the Laplace transform of various functions. A modern treatment is given of periodic impulses of finite and infinitesimal duration, based upon complex integration. The examples included are an integral part of the text, for they contain important formulas and additional theorems.

POWER FROM THE WIND. By P. C. Putnam. D. Van Nostrand Company, Toronto, Ontario, Canada, New York, N. Y., and London, England, 1948. 224 pages, illustrations, diagrams, charts, maps, tables, 9½ by 6 inches, cloth, $6. Of interest to those investigating new sources of power, this is the record of the wind-turbine experiment conducted in Vermont by a group of eminent scientists and engineers. The purpose of the work was to find out the possibilities of generating electricity on a large scale by harnessing the wind. The book summarizes the various technical problems encountered, the attempts at solving them, and the finding and discoveries made.

INDEX TO ASTM STANDARDS, DECEMBER 1947. American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa. 248 pages, 8½ by 5¾ inches, paper, free upon request. This index provides a ready reference for locating any of the some 1,500 standards and tests issued by the ASTM. It also serves those who wish to determine whether ASTM has issued standard specifications, test methods, or definitions covering a particular engineering material or subject.

MANAGEMENT PROCEDURES IN THE DETERMINATION OF INDUSTRIAL RELATIONS POLICIES. By H. Baker. Princeton University, Industrial Relations Section, Research Report Series number 76, 1948. 81 pages, tables, 9¼ by 6 inches, paper, $2. This report considers the allocation of responsibility for final decisions on major personnel policies, as well as the procedures followed on their formation. Information was gathered from 84 companies with considerable experience in handling industrial relations problems. Including only companies engaged primarily in manufacturing, consideration is given to the representative nature of the group in respect to size and industry.

PREPARATION AND CHARACTERSITICS OF SOLID LUMINESCENT MATERIALS, Symposium held at Cornell University, October 24–26, 1946, sponsored by the Division of Electronic Optics of the American Physical Society, edited by G. R. Fonda and F. Seitz. Published under the auspices of the National Research Council by John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 459 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, $5. The 29 papers that appear in this monograph are the outcome of a conference on luminescence held at Cornell University in October 1946. The material presented is a survey of present researches and affords a comprehensive review of accomplishments of the war years. General characteristics and methods of preparation, recent developments in theory and experiment, factors affecting fluorescence characteristics, storage of luminescence energy, and miscellaneous aspects of fluorescence are considered.

PRINCIPLES OF PERSONNEL TESTING. By C. H. Lawshe, Jr. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 225 pages, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. A practical treatment of the accepted procedure for selecting, validating, and using personnel tests in business and industrial situations. Comprehensive in scope but simple in presentation, the book covers the various types of tests and cites pertinent examples from the literature to indicate those kinds of situations in which specific kinds of tests have been useful.

PRINCIPLES OF SERVOMECHANISMS, DYNAMICS AND SYNTHESIS OF CLOSED-LOOP CONTROL SYSTEMS. By G. S. Brown and D. P. Campbell. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 400 pages, illustrations, diagrams, charts, tables, 9¼ by 5¾ inches, cloth, $5. Of interest to the scientist, practicing engineer, teacher, and student, this book offers a comprehensive treatment of closed-loop dynamics and synthesis. It describes the principles of the closed-loop automatic control, stressing actual system design, and offers a direct approach to system synthesis by interrelating the transient and frequency behavior.

RADAR, WHAT RADAR IS AND HOW IT WORKS. By O. E. Dunlap, Jr. Reviewed edition. Harper and Brothers, New York, N. Y., 1948. 268 pages, illustrations, diagrams, 8¼ by 5¼ inches, cloth, $3. This popularly written book tells the story of radar without equations or technical language, so that the layman may appreciate the significance of radar. This new edition explores the postwar advances and provides information on how radar is being adapted to scores of peacetime uses.

TABLES OF BESSEL FUNCTIONS OF FRACTIONAL ORDER. Prepared by the Computation Laboratory of the National Applied Mathematics Laboratories, National Bureau of Standards, volume I. Columbia University Press, New York, N. Y., 1948. 413 pages, 10¾ by 7¾ inches, cloth, $7.50. The purpose of this book is to provide tables of Bessel functions of fractional orders, other than one-half, which frequently occur in practical applications. The fractional orders of one-quarter, one-third, two-thirds, and three-quarters are given to either ten decimal places or ten significant figures. A bibliography on Bessel functions also is included. The present volume contains tables of $J_v(x)$, while a companion volume, to be published later, will give the tabulation of $I_v(x)$.

TECHNICAL DESCRIPTIVE GEOMETRY. By B. L. Wellman. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 508 pages, diagrams, tables, 9¼ by 6 inches, cloth, $4. Providing students and draftsmen with a complete up-to-date treatment, this book is written in simple language and generously illustrated It begins with the most elementary concepts and progresses by easy stages to the complex intersection and development problems found in modern applications. Practical situations have been emphasized, especially with respect to surfaces. Double-curved surfaces, so important in ship, automobile and aircraft instruction, are given more than usual space.

TWO-DIMENSIONAL FIELDS IN ELECTRICAL ENGINEERING. By L. V. Bewley. Macmillan Company, New York, N. Y., 1948. 204 pages, illustrations, diagrams, charts, tables, 9½ by 6 inches, cloth, $5.50. Based on a course given to first semester seniors at Lehigh University, this book comprises a collection of field problems encountered by electrical engineers. It bridges the existing gap in the consideration of fields by the undergraduate curricula, and introduces students to the methods and procedures of mathematical physics. A knowledge of calculus and differential equations is assumed.

WORK OF THE WELDED RESEARCH TEAM AT THE UNIVERSITY OF BIRMINGHAM, JULY 1944 TO JANUARY 1947. Research Report number 1 published by Aluminum Development Association, 33 Grosvenor Street, London, W. 1, England, December 1947. 35 pages, charts, tables, 10¾ by 8 inches, paper, apply. Summarizes the results of an extended series of investigations on the welding of aluminum alloys. The major object was to investigate the correlation between hot-shortness and welding properties by means of ring-casting, restrained-weld, and high-temperature-tensile tests, and to determine the most suitable alloys for welding purposes. Suggestions are made as to the trend of the work that remains to be done.

WORKSHOP YEARBOOK AND PRODUCTION ENGINEERING MANUAL (II). Edited by H. C. Town. Paul Elek Publishers Ltd., 38 Hatton Garden, London, E. C. 1, England, 1947. 568 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, 35s. Provides data valuable to the production engineer, the designer, and the engineering student. It is divided into three sections, the first consisting of a series of specialized articles on modern machine tool developments. Section 2 covers a wide field of engineering progress, including power transmission, industrial developments, precision tools and methods of machining, and offers descriptions of the latest machine tools. In section 3 are abridged articles from British and American sources providing the latest information on machine design, press operations, gauging and inspection, metal and heat treatment, welding, electric and other drives, and controls.

BATTLEFRONTS OF INDUSTRY, WESTINGHOUSE IN WORLD WAR II. By D. O. Woodbury. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 342 pages, illustrations, 9¼ by 6 inches, cloth, $3.50. This book, which shows how American industry worked during the last war, is primarily the story of Westinghouse's contributions. Such products as electric torpedoes, jet propulsion units, and atom bomb manufacturing equipment are considered. Two chapters on fissionable materials are included.

CATHODE RAY TUBE DISPLAYS. (Massachusetts Institute of Technology, Radiation Laboratory Series number 22.) Edited by T. Soller, M. A. Starr, and G. E. Valley, Jr. McGraw-Hill Book Company, New, York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 746 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $10. Presents a practical discussion of basic characteristics, principles of operation, and methods of application. The design and construction of beam deflection and focusing devices, optical projection and measuring apparatus, and auxiliary mechanical equipment are explained. A compilation of design techniques, whereby instruments using cathode-ray tubes as major components can be synthesized to fulfill various functions, comprises a major portion of the book.

ÉQUIPMENT THERMIQUE DES USINES GÉNÉRATRICES D'ÉNERGIE ÉLECTRIQUE. By J. Ricard, preface by E. Mercier. Second edition. Dunod, Paris, France, 1948. 659 pages, illustrations, diagrams, charts, tables, 9½ by 6¼ inches, paper, 2,900 frs. This comprehensive text on the thermal equipment of electric generation plants covers in detailed

form the following topics: steam cycles; heat transmission and heat exchangers; fuels and combustion; steam boilers and boiler furnaces; feed-water treatment; condensers and auxiliary equipment; steam turbines; plant construction, layout, and economics; selection of equipment and operative procedure; and the simultaneous production of steam and electric energy.

FUNDAMENTALS OF ELECTRICAL ENGINEERING. By V. P. Hessler and J. J. Carey. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London England, 1948. 241 pages, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, \$3.50. Intended for use by second year electrical engineering students this text is designed to give a thorough understanding of the concepts of electricity and magnetism. The outstanding feature is the extensive treatment given unit systems and dimensional analysis. A background of electricity and magnetism from engineering physics, and integral calculus is assumed. Numerous problems follow each chapter.

(A) GUIDE TO TECHNICAL WRITING. By W. G. Crouch and R. L. Zetler. Ronald Press Company, New York, N. Y., 1948. 401 pages, illustrations, diagrams, charts, tables, $9\frac{1}{2}$ by 6 inches, cloth, \$4. Covers both the techniques of various kinds of communications and the principles of writing. The business letter, technical article, report, abstract, and types of oral communication are considered in the first section. The chapter, "Language Essentials," reviews the fundamental principles, while the "Index to English Usage" has been limited to essentials of English and grammar which technical men must employ.

INDUSTRIAL ELECTRONICS REFERENCE BOOK. By electronics engineers of the Westinghouse Electric Corporation. John Wiley and Sons, Inc., New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 680 pages, illustrations, diagrams, charts, tables, 12 by $8\frac{3}{4}$ inches, cloth, \$7.50. The work of 37 Westinghouse experts, this comprehensive book gives both the theoretical data and application information necessary to determine the possibilities and limitations of electronic devices. It covers fundamental theory; design, operation and construction of electronic tubes; electronic circuit components; circuits for different types of tubes; application to transmission lines and antennas; and many different types of industrial equipment.

AN INTRODUCTION TO COLOR. By R. M. Evans. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1948. 340 pages, colored plates, diagrams, charts, tables, $9\frac{3}{4}$ by 7 inches, linen, \$6. Covers the combined effects of the physical properties of light, the properties of vision itself, and the action of the mind in interpreting color. It is a completely nonmathematical text, and only a knowledge of the first principles of physics and psychology is assumed. There are sections which are of interest to photographers, artists, designers, engineers, and manufacturers of paints, textiles, and colored papers.

JOB EVALUATION, A BASIS FOR SOUND WAGE ADMINISTRATION. By J. L. Otis and R. H. Leukart. Prentice-Hall, Inc., New York, N. Y., 1948. 473 pages, diagrams, charts, tables, $9\frac{1}{2}$ by 6 inches, linen, \$6.65. Of interest to the executive, union leader, and student, this book delineates the principles of sound wage and salary administration based upon job evaluation. It presents the principles together with illustrations of techniques. Several individual systems are presented so that the reader may select one and adapt it to his own particular uses. A bibliography of the articles and books written during the years 1943–46 is included.

METALS HANDBOOK, 1948 EDITION. Prepared under direction of the metals handbook committee, edited by T. Lyman. American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio, 1948. 1444 pages, illustrations, diagrams, charts, maps, tables, 11 by 8 inches, fabrikoid, \$15. Provides accurate technical data, specific meanings, and significant facts concerning the full range of metallurgical subjects. More than 500 individuals contributed to the revised and enlarged edition. Articles dealing with metals, processes, or methods in general are in the first section. The second section, on ferrous metals, contains new material on alloying elements in steel, and hardenability. The nonferrous section has been expanded and almost entirely rewritten, with quick-reference semitabular arrangements of the properties of nonferrous metals and alloys. The first extensive collection of alloy phase diagrams to be published in America are in the fourth and concluding section on the constitution of alloys.

MODERN PLASTICS ENCYCLOPEDIA, 1948. Plastics Catalogue Corporation, 122 East 42d Street, New York, N. Y. 1,673 pages, illustrations, diagrams, charts, tables, $11\frac{1}{2}$ by $8\frac{1}{4}$ inches, fabrikoid, \$8.50. In addition to the material presented in the 1947 edition, there is an up-to-date catalogue of stock-molded parts, cast shapes, and extrusions. A new section has been added on plastic film and sheeting, presenting recent developments and listing characteristics and production data for the various film types. Other new articles include information on hydroxyethyl cellulose, inorganic plastics, chemicals for plastics, synthetic bristles, pulp molding, and laminating and resin plant equipment.

QUALITY CONTROL. By N. L. Enrick. Industrial Press, New York, N. Y.; Machinery Publishing Co., Ltd., National House, West Street, Brighton, 1, England, 1948. 122 pages, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, fabrikoid, \$3. This book intended for the practical man explains statistical quality control in generally understandable terms. The author has confined himself to the essential methods and purposely has omitted all unnecessary refinements and formulas. The two concluding chapters show where and how statistics and probability enter into modern inspection.

QUALITY CONTROL IN INDUSTRY, METHODS AND SYSTEMS. By J. G. Rutherford. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 201 pages, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, \$3.50. Recommended as a text in industrial engineering courses, this book is also a reference manual for industrial engineers, executives, and supervisors. It covers the organization, administration, and functions of a department. Explaining and illustrating the actual methods of installation, it also gives complete data for the introduction, design and use of statistical sampling techniques.

ROCKETS, GUNS, AND TARGETS. (Science in World War II, Office of Scientific Research and Development.) By J. E. Burchard, with a foreword by R. C. Tolman. Atlantic Monthly Press Book, Little, Brown and Company, Boston, Mass., 1948. 482 pages, charts, tables, $8\frac{3}{4}$ by $5\frac{1}{2}$ inches, cloth, \$6. Describes the work of three divisions of the National Defense Research Committee. Two were concerned with propulsion of missiles and the third with terminal ballistics. The development of solid-fuel recoilless weapons and related devices is presented as well as the work on the control of gun erosion, design, and construction. The difficulties characteristic of wartime administration are described.

REFRESHER NOTES, HYDRAULICS, THERMODYNAMICS, MACHINE DESIGN, FOR PROFESSIONAL ENGINEERS LICENSE EXAMINATION. By J. D. Constance, author and publisher. 506 Olympia Avenue, Cliffside Park, N. J., 1948. Paged in sections, illustrations, diagrams, charts, tables, $11\frac{1}{4}$ by $8\frac{3}{4}$ inches, paper, \$4.50. Designed for those who have once studied the subjects included, this review course presents the fundamental concepts, methods, and practical applications of the basic engineering sciences, including hydraulics, thermodynamics, and machine design. For the most effective use, the material has been restricted to the essentials needed for the comprehensive collection of sample problems given. Detailed solutions are worked out for a wide variety of these problems.

ALTERNATING CURRENT MACHINES. By T. C. McFarland. D. Van Nostrand Company, Toronto, Ontario, Canada, New York, N. Y., London, England, 1948. 540 pages, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, \$6. Each chapter of this new textbook represents a broad subdivision of the general topic, thus preserving the logical unity of the several topics while allowing the instructor to do his own choosing of the order of presentation. These separate chapters cover single-phase and special-purpose transformers, polyphase transformations, induction machines, synchronous machines, both mechanical- and electronic-type power converters, single-phase motors, and a-c motor controls.

RADAR SCANNERS AND RADOMES. (Massachusetts Institute of Technology, Radiation Laboratory Series, number 26.) Edited by W. M. Cady, M. B. Karelitz, and L. A. Turner. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 491 pages, illustrations, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, \$7. The first part of this book takes up the problems of mechanical and electrical engineering and of servo design which underlie the design of scanners for practical radar sets. Land-based, ship-borne, and air-borne scanners are treated, and gyroscopically-controlled antenna stabilization discussed. The second part is devoted principally to the practical mechanical, electrical, and aerodynamic problems of the design of radomes (housing for scanners), including discussion of the properties of the most useful materials, and some development of the theory of the effects of such housings on the radiated waves.

ASTM STANDARDS INCLUDING TENTATIVES, 1947 supplement, 5 parts. Part IA, "Ferrous Metals," 403 pages. Part IB, "Nonferrous Metals," 319 pages. Part II, "Nonmetallic Materials—Constructional," 463 pages. Part IIIA, "Nonmetallic Materials—Fuels, Petroleum, Aromatic Hydrocarbons, Soaps, Water, Textiles," 437 pages. Part IIIB, Nonmetallic Materials—Electrical Insulation, Plastics, Rubber, Paper, Shipping Containers, Adhesives," 305 pages. American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa., 1947–1948. Illustrations, diagrams, charts, maps, tables, 9 by 6 inches, paper, \$4 each. These supplements give in their latest approved form some 330 specifications, tests, and definitions which either were issued for the first time in 1947 or revised since their appearance in the 1946 book. The five separate parts correspond to the division of the triennially published complete "Book of ASTM Standards."

APPLIED PHYSICS (SCIENCE IN WORLD WAR II). ELECTRONICS, edited by C. G. Suits with a foreword by K. T. Compton. OPTICS, by H. K. Stephenson and E. L. Jones, edited by G. R. Harrison. METALLURGY, by L. Jordan. Little, Brown and Company (Atlantic Monthly Press Book), Boston, Mass., 1948. 456 pages, illustrations, diagrams, tables, $8\frac{1}{2}$ by $5\frac{1}{2}$ inches, cloth, \$6. Written for both the layman and the scientist, this volume continues the report on the work of the Office of Scientific Research and Development. The first section is concerned with electronics and evaluates the work done on radar countermeasures, other related fields, and the propagation of airwaves. The second section deals with optical instruments of all kinds. It also discusses the work done on sound control and land-mine countermeasures. In the third section are descriptions of the work done on aircraft metals, armor, guns, metals for particular services, and an examination of enemy materiel.

ELECTRIC POWER STATIONS, volume I. By T. H. Carr, with a foreword by Sir L. Pearce. Third edition revised and enlarged. Chapman and Hall, Ltd., London, England, 1947. 513 pages, illustrations, diagrams, charts, tables, $8\frac{3}{4}$ by $5\frac{1}{2}$ inches, cloth, 36s. The opening chapters deal briefly with the fundamentals of station design and construction. Succeeding chapters give detailed information on the following major topics: circulating water systems; cooling towers; coal-handling plant; ash-handling plant; pipework; turbines; and a large section covering the boiler plant. A bibliography accompanies each chapter.

(The) ELECTRON MICROSCOPE. By D. Gabor. Chemical Publishing Company, Brooklyn, N. Y., 1948. 164 pages, illustrations, diagrams, charts, tables, $8\frac{1}{4}$ by $5\frac{1}{4}$ inches, cloth, \$4.75. Both an introduction to the use of the electron microscope and a critical contribution to its theory. The fundamentals of electron optics are explained briefly in the early chapters. The concluding chapters on future developments and chemical and structural analysis are more advanced. An appendix considers the diffraction theory of the microscope.

FLUORESCENT AND OTHER GASEOUS DISCHARGE LAMPS. By W. E. Forsythe and E. Q. Adams. Murray Hill Books, Technical Division, New York, N. Y., and Toronto, Ontario, Canada, 1948. 292 pages, illustrations, diagrams, charts, tables, $9\frac{1}{4}$ by 6 inches, cloth, \$5. Starting with the earliest beginnings of the fluorescent lamp, this book takes the reader through an analytical treatment of the factors influencing the design, construction, operation, and performance of gaseous discharge lamps including many lesser known types. From an introduction to light, radiation, and the discharge of electricity through gases, it progresses to complete coverage of fluorescent light principles, components, problems, efficiency, and related factors.

CHEMICAL AND ELECTRO-PLATED FINISHES. By H. Silman, foreword by H. Moore. Chapman and Hall, Ltd., London, England, 1948. 414 pages, illustrations, diagrams, charts, tables, $8\frac{3}{4}$ by $5\frac{1}{2}$ inches, cloth, 30s. A reasonably comprehensive account of

modern industrial metal-finishing processes, together with the chemical and physical principles involved. It is of interest to engineers and designers and those concerned more directly with the scientific and technical aspects of metal finishing, both from the process and plant angles.

CONTROL OF ATOMIC ENERGY. By J. R. Newman and B. S. Miller. McGraw-Hill Book Company, Whittlesey House Division, New York, N. Y., and Toronto, Ontario, Canada, 1948. 434 pages, diagrams, tables, 8¹/₄ by 5¹/₂ inches, cloth, $5. Presenting a detailed and comprehensive analysis of the problem, this book studies the underlying philosophy of the Atomic Energy Act and its influence on business and industry. It describes the organization and structure of the Atomic Energy Commission and indicates the general pattern of controls prescribed by Congress. The production and ownership of fissionable materials, radioactive by-products, industrial and commercial uses, patents, research, and military applications are discussed.

DESIGN OF MACHINE ELEMENTS. By M. F. Spotts. Prentice-Hall, Inc., New York, N. Y., 1948. 402 pages, illustrations, diagrams, charts, tables, 9¹/₄ by 6 inches, cloth, $6.65. This book opens with a survey of prerequisite theory, and continues with consideration of individual machine elements. Methods based on rational analysis are utilized. Well-known basic theories of design are presented as well as some of the newer methods. The text contains many illustrative examples and solutions, besides a large number of problems to be worked by the student.

SAMPLING INSPECTION by the Statistical Research Group, Columbia University. Edited by H. A. Freeman and others. McGraw-Hill Book Company, New York, N. Y., and London, England, 1948. 395 pages, charts, tables, 9¹/₄ by 6 inches, cloth, $5.25. Deals first with the elementary concepts of acceptance sampling, supplies a standard sampling-inspection plan, and gives detailed instructions so that the principles developed and the plans provided can be used for practical inspection of industrial products. In addition to providing single, double, and sequential plans for various *AQL* classes, for use with any lot sizes, the operating characteristic of each plan is provided.

(The) SCIENCE OF CLOCKS AND WATCHES. By A. L. Rawlings. Second edition. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 303 pages, diagrams, charts, maps, tables, 9 by 6 inches, cloth, $5. Thoroughly covers the theory and the history of watch and clock making. Dealing with the aspects of watch and clock design from the engineering standpoint, it contains practical suggestions for both horologists and manufacturers. New material has been added in this edition on apparatus for star observations, use of quartz oscillators, the Shortt "free pendulum" clock, striking clocks, and automatic winding.

SUNSPOTS IN ACTION. By H. T. Stetson, with a foreword by Sir Edward V. Appleton. Ronald Press Company, New York, N. Y., 1947. 252 pages, illustrations, diagrams, charts, tables, 8³/₄ by 5³/₄ inches, cloth, $3.50. Brings together what is known about sunspots, gathering relevant information from several fields of science. The author outlines the factual evidence available, and examines critically some of the more plausible hypotheses advanced. Emphasis is placed on the effect of the sun on the earth's atmosphere, both as a medium for long distance radio communication, and as an ultimate source of weather. In addition, evidence is presented relating to the effects of sunspots on life cycles in plants and animals and as to possible correlation of sunspots with economic trends.

SURVEY OF PERSONNEL PRACTICES IN LOS ANGELES COUNTY AS OF AUGUST 1, 1947, Bulletin number 14. Compiled by R. O. Sensor and M. F. Martin. California Institute of Technology, Industrial Relations Section, Pasadena 4, Calif. 45 pages, tables 11 by 8¹/₂ inches, paper, $2.50. This condensed study covers work schedules, premium pay, incentive pay plans, wage schedules, job evaluation plans, holiday pay, shift differentials, and union representation. The information is presented in the form of detailed tables, and directions for the effective use of the data are given in the introduction.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Modern Management Practices and Problems. Lists progress and trends in seven fields of management. Sells for $1. American Management Association, 330 West 42 Street, New York 18, N. Y.

Index to ASTM Standards. Issued May 1948, this index is revised up to December 1947. 240 pages. Furnished without charge upon written request to the American Society for Testing Materials Headquarters, 1916 Race Street, Philadelphia 3, Pa.

The Fracture of Metals. 58-page booklet in two parts. Part 1 includes a survey of literature and an analysis of theories. Part 2 supplements Part 1 and clarifies new developments. Price $1. Obtainable from American Welding Society Headquarters, 33 West 39th Street, New York 18, N. Y.

Notes on Linear and Angular Accelerometers. On the measurement of applied forces in the dynamic testing of vehicles. Furnished free by Schaevitz Engineering, 226 Harding Avenue, Collingswood, N. J.

Bibliography on Industrial Radiology 1945–1948. 300 references. Priced at $2 from the St. John X-Ray Laboratory, Califon, N. J.

Ionospheric Radio Propagation. National Bureau of Standards publication. 209 large pages; 205 figures. $1 per copy, available from the Superintendent of Documents, United States Printing Office, Washington, D. C.

Electric Eye Circuits and Relays in Theory and Practice. Explains numerous details of the design and use of photorelays. 40 pages; 50 figures. $1 per copy from the EBY Specialty Sales Company, 220 East 23d Street, New York, N. Y.

Bituminous Coal Facts and Figures. Data book about coal, profusely illustrated with graphs, pictograms, and photographs. Contains information about coal, including facts about reserves, distribution, consumption, mechanization, manpower, and others. 148 pages. Available from the Bituminous Coal Institute, Southern Building, Washington, D. C.

Transit Fact Book. Published by the American Transit Association, this is the annual summary of basic data and trends in the transit industry of the United States. Available from the American Transit Association office, 292 Madison Avenue, New York 17, N. Y.

Bimonthly Supplement, Inspected Appliances, Equipment, Materials. August 1948 edition, published by Underwriters' Laboratories, 161 Sixth Avenue, New York, N. Y. as a service to industry.

Tempil Topics, Volume 3, Number 10. "Stainless Steel." Given on request to the Tempil Corporation, 132 West 22d Street, New York 10, N. Y. Gives concise data on characteristics of stainless steels and recommended procedure for fabrication and welding.

Basic Radio Propagation Predictions for December 1948, three months in advance, CRPL Series D. Number 49. A National Bureau of Standards publication. Ten cents per copy, from the Superintendent of Documents, United States Government Printing Office, Washington, D. C.

Aspects of Galvanic Corrosion. The booklet discusses various aspects of galvanic corrosion. Prepared under the supervision of the International Nickel Company's engineering section, it is designed for the production man as well as the research engineer. The booklet covers some of the factors influencing galvanic corrosion and presents data on how galvanic effects can be minimized. It is available without cost from The International Nickel Company, New York, N. Y.

Compounds. This handbook includes the physical characteristics, active formulas, facts and figures and suggested applications of standard and high melting point impregnating and dipping waxes, cable saturating and finishing waxes, synthetic cerosines, capacitor end seals, screw hole fillers, socket cements, oil-resistant seals, filled and unfilled potting compounds, rubber seals, storage battery seals, and the five methods of testing such materials: ring and ball softening point, melting point drip method, cold flow temperature, pouring temperatures, penetrations, and viscosity. This manual includes all the facts and figures essential to the proper evaluation and uses for the materials included. Copies may be obtained by writing the Mitchell-Rand Insulation Company, 51 Murray Street, New York 7, N. Y.

Survey of Personnel Practices in Los Angeles County. The following personnel practices are included in the book: work schedules, premium pay, incentive pay plans, wage schedules, job evaluation plans, holiday pay—hourly workers, holiday pay—salaried workers, shift differentials, and union representation. Published by the Industrial Relations Section, California Institute of Technology, Pasadena 4, Calif. Price $2.50. Available from the book store of the California Institute of Technology. Bulletin Number 14.

Investigation of Overcurrent Protection Devices as Affected by Ambient Temperatures. Research Bulletin No. 41. Reports of operating difficulties under service conditions involving extreme cold weather prompted an investigation of overcurrent protection devices to determine the effect of ambient temperature on their performance. The findings confirm a view previously held that thermally operated devices are affected by the ambient temperature at which they are operated and this should be taken into account in actual practice. Write to Underwriters' Laboratories, Inc., Chicago 11, Ill., for copy of your pamphlet.

Save 2 Ways!

1. Simplified contact groups speed contact inspections.

2. Large manhole with hinged cover permits easy access to tank interior.

3. Double-hinged doors uncover operator and allied equipment on 3 sides.

4. Removable hood allows speedy adjustments of pole unit mechanism and transformer connections.

5. Bushing transformers in wells . . . removed from top or down through tank without removing bushings.

6. Fill valve (top) and combined drain and sampling valve for oil handling.

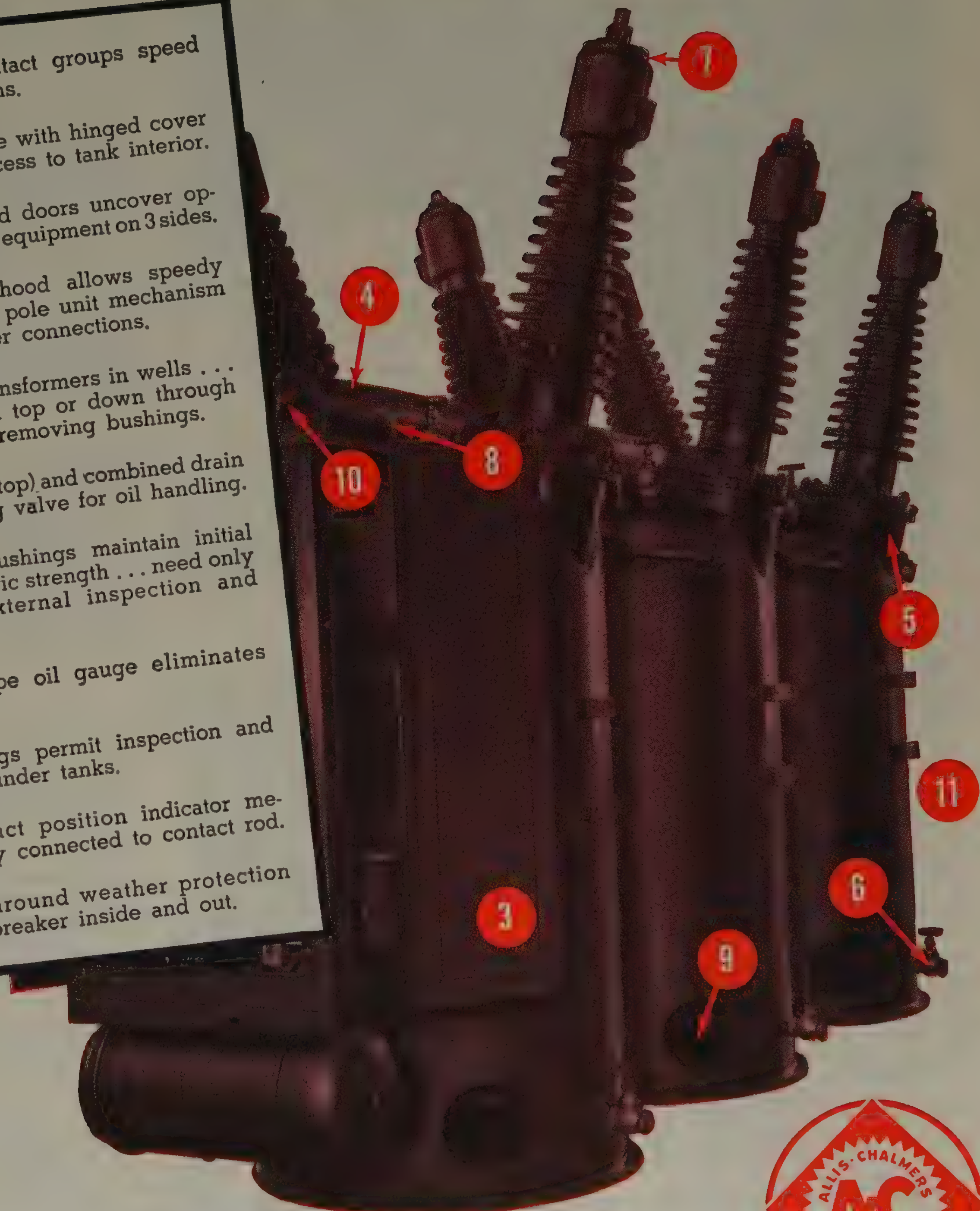
7. Sealed bushings maintain initial high dielectric strength . . . need only periodic external inspection and cleaning.

8. Float-type oil gauge eliminates leakage.

9. Openings permit inspection and cleaning under tanks.

10. Contact position indicator mechanically connected to contact rod.

11. All-around weather protection guards breaker inside and out.



Call Allis-Chalmers for power circuit breakers — in standard ASA ratings . . . Indoor and Outdoor!

ALLIS-CHALMERS

Pioneers in Power and Electrical Equipment From Generation Through Utilization

INDUSTRIAL NOTES . . . .

New Plant. Allis-Chalmers has announced completion of the new Columbus plant at the company's Pittsburgh works, which will boost Pittsburgh transformer manufacturing capacity 40 per cent. This plant is the largest single item in a $2,000,000 expansion program now practically complete and will be devoted to the processing of steel previous to assembly in transformers in the other four plants located on an eight-acre area on Pittsburgh's North Side. The plant includes a complete new layout of annealing furnaces for core steel. This battery of electric furnaces will provide control to within a few degrees at the annealing temperature. Core steel fabrication also has been speeded with a new 600-kw infrared oven and conveyer system. A whole section of the new plant is devoted to additional facilities for winding cores for the company's new wound-core distribution transformers; another section to testing 50 radiators simultaneously, all under pressure, to check for slightest brace of an oil leak.

Vibrators. Octave Blake, president of Cornell-Dubilier Electric Corporation of South Plainfield, N. J., has announced that the corporation is adding to its line of capacitors a line of vibrators. The new products are light duty vibrators and vibrator power supplies. The light duty vibrators are a development of the Cornell-Dubilier engineering laboratories and are used principally in automobile radio equipment to furnish the necessary a-c power from storage batteries. Also through the purchase of The Electronic Laboratories, Inc., Indianapolis, Ind., the corporation has acquired a recently improved and new design of heavy duty vibrator and vibrator power supply. These products are used in industrial equipment, such as converters and frequency changers for the operation of electric razors on Pullman cars, new and improved fluorescent lighting on busses, radio transmitters, d-c television, and so forth.

Appointment. E. B. Bremer has been appointed electrification manager in the northwestern district for Westinghouse Electric Corporation. Mr. Bremer is a veteran of 30 years with Westinghouse, having joined the corporation in 1918 as a salesman. He was later made manager of appliance electrification sales at the East Springfield, Mass., works. In 1935 he returned to the northwestern district as manager of the small motors section of the industrial division. During World War II, from 1942 to 1945, he served as a lieutenant commander in the United States Naval Reserve.

New Engineering Firm. Charles J. Wurmfeld and Eric Singleton have resigned from Gibbs and Cox to open their own engineering offices at 150 Nassau Street, New York, N. Y. Mr. Wurmfeld had been with Gibbs and Cox for the past 14 years in charge of all steam heating on Naval vessels and Liberty ships. Mr. Singleton was associated with him for six years in the hull piping department and on factory design. Prior to this association, he had had long experience as a builder.

Appointment. Nathaniel C. Fick has been appointed deputy executive director of the Committee on Basic Physical Sciences, Research and Development Board, with offices in the Pentagon Building, Washington, D. C. Mr. Fick has been metallurgist with Battelle Memorial Institute for the past five years. Previous associations have been with the Carnegie-Illinois Steel Corporation, Purdue University, United States Steel Research Laboratory, Tennessee Coal, Iron and Railroad Company, Prest-O-Lite division of the Union Carbide and Carbon Corporation, and the Basca Manufacturing Company.

GE Appointment. George F. Murphy has been appointed manager of the equipment development works of General Electric Company's electronics department, In this capacity Mr. Murphy will head the activity that is responsible for design and development of machinery and equipment for the department's manufacturing operations. His headquarters will be in Schenectady, N. Y. He has been with the company since 1913.

Removal Notice. Bendix International, a division of Bendix Aviation Corporation, has announced the removal of its offices to 72 Fifth Avenue, New York 11, N. Y., Telephone Gramercy 7-3100.

Manager. A. H. Graham has been appointed manager of General Electric's d-c armored motor engineering division, small and medium motor divisions, Erie works. Mr. Graham joined General Electric on the test course in 1939. Later he worked on the design and development of traction generators and motors, Mr. Graham has been section engineer, design section, d-c armored motor engineering division since September 1947.

Standards Appointment. Doctor Robert D. Huntoon has been appointed chief of the atomic and molecular physics division of the National Bureau of Standards. He also will serve as consultant to the electronics standards and ordnance development laboratories of the electronic division. Doctor Huntoon has received wide recognition in numerous scientific fields, including atomic-beam measurement, special amplifiers, atomic particle counting, electronic ordnance devices, the phasing of oscillators, and the study of the deuteron-deuteron nuclear reaction.

(*Continued on page 25A*)

INDUSTRIAL NOTES *(Continued from page 16A)*

Vice-President. Richard G. Robbins has been promoted from sales manager of Hubbard and Company to divisional vice-president. Mr. Robbins started with Hubbard and Company in 1923 as a general assistant to several department heads. In a few years he was placed in charge of advertising, and later was transferred to the sales department, first as assistant sales manager, eastern division, then as sales manager, and now to his present post as divisional vice-president.

Appointment. Thomas Morrin has been appointed chairman of electrical engineering research at Stanford Research Institute. Before joining the institute staff, Mr. Morrin was chief of the mircowave engineering department of the Raytheon Manufacturing Company.

Stromberg-Carlson Appointment. Benjamin P. Shiro has been appointed plant manager of the Stromberg-Carlson's Erie, Pa., plant. Mr. Shiro was formerly with the company in charge of cabinet design.

Vice-President Election. Raymond R. Rausch has been elected a vice-president of the General Electric Company and will be in charge of company manufacturing policy, succeeding Elmer D. Spicer, who retired September 30 under provisions of the company's pension plan. Mr. Rausch has been serving as a member of the manufacturing group on Mr. Wilson's staff since he joined General Electric in 1947.

TRADE LITERATURE • • •

Arc Welding Electrode Catalog. 40 pages, Contains 50 photographs and diagrams, an electrode selector chart, and details on all the electrodes of the line. Data are supplied on general description, application, welding procedure, mechanical properties, and specifications. Write for copy to Wilson Welder and Metals Company, Inc., 60 East 42d Street, New York 17, N. Y.

Electric Motors. The Lima Electric Motor Company's Bulletin *MB-1* describes the company's line of electric motors including drip-proof induction motors and motors built to special specifications. For further information write The Lima Electric Motor Company, Department K, Lima, Ohio.

Microcastings. "New Horizons with Microcastings," 16-page booklet published by Austenal Laboratories, Inc., contains many examples of parts produced by the Microcast process. The book is fully illustrated and also lists parts suitable for quantity production by this technique as well as range and type of alloy. Physical and chemical properties of Vitallium

(Continued on page 28A)

for A-M BROADCAST MEASUREMENTS

TYPE 1931-A MODULATION MONITOR

TYPE 1932-A DISTORTION & NOISE METER

General Radio Company has supplied precise measuring equipment for broadcast stations for over twenty years. G-R instruments are designed for accuracy, ease of operation and long, trouble-free life. G-R broadcast instruments are quality instruments designed specifically for broadcast station use.

These two meters are standard equipment in most a-m broadcast stations; they are essential "musts" where transmitters and associated station equipments are to be operated continuously at peak efficiency.

The Modulation Monitor indicates continuously the percentage amplitude modulation of broadcast and other radiotelephone transmitters. The Distortion & Noise Meter measures the a-f distortion in transmitters or audio equipment such as line and speech amplifiers. It finds many uses in communications laboratories and in production testing of radio receivers.

FEATURES

The Type 1931-A Modulation Monitor allows the following measurements to be made continuously: Percentage Modulation on either positive or negative peaks; Program-level monitoring; Measurement of shift of carrier when modulation is applied; Transmitter audio-frequency response.

Requires r-f input of only 0.5 watt; carrier frequency range 0.5 to 60 Mc; terminals for remote indicator; distortion less than 0.1%; 600-ohm audio output circuit for audible monitoring; modulation percentage range 0 to 110%; flashing over-modulation lamp operates over 0 to 100% on negative peaks; overall accuracy at 400 cycles is 2% of full scale at 0% and 100% and 4% at any other modulation percentage; a-f frequency response of meter indication is constant within 1.0 db between 30 and 15,000 cycles when used with the Type 1932-A Distortion & Noise Meter.

Type 1931-A Modulation Monitor $395.00

FEATURES

The Type 1932-A Distortion & Noise Meter is continuously adjustable over the audio-frequency range and can be set to any frequency quickly, since it has only one main tuning control plus a small trimmer. With it measurements can be made on a-f distortion in radio transmitters, line amplifiers, speech amplifiers, speech input equipment to lines; noise and hum levels of a-f amplifiers, wire lines to the transmitter, remote pick-up lines and other station equipment are made with ease.

Full-scale deflections on the large meter read distortions of 0.3%, 1%, 3%, 10% or 30%; range for carrier noise measurements extends to 80 db below 100% modulation, or 80 db below an a-f signal of zero dbm level. The a-f range is 50 to 15,000 cycles, fundamentals, for distortion measurements and 30 to 45,000 cycles for noise and hum.

Type 1932-A Distortion & Noise Meter . . $575.00

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

90 West St., New York 6 — 920 S. Michigan Ave., Chicago 5 — 950 N. Highland Ave., Los Angeles 38

TRADE LITERATURE (*Continued from page 25A*)

castings produced by this method also are given. Obtain your copy from Austenal Laboratories, Inc., at 715 East 69th Place, Chicago 37, Ill., or at 224 East 39th Street, New York 16, N. Y.

Mallory Rectifier Stack. A one-page engineering bulletin on Mallory rectifier stack 6/12-volt 100/50-ampere fast chargers plus diagrams showing various types of wiring. Write P. R. Mallory and Company, Inc., 3029 East Washington Street, Indianapolis 6, Ind., for further information.

Sprague Prokar Capacitors. Engineering Bulletin #211 gives full details concerning these capacitors which are said to be the smallest molded tubulars ever produced. They are suited for electrical or electronic application in which size, temperature, humidity, and physical stress are dominant considerations. Write to Sprague Electric Company, North Adams, Mass., for your copy.

Broadcast Transmitters. 24 pages. A Radio Corporation brochure, entitled "AM Broadcast Transmitters, Types BTA-5F and 10F," contains simplified schematic diagrams of transmitter circuits, specifications on the operation of the transmitters, suggested layouts of the equipment

(*Continued on page 34A*)

TRADE LITERATURE (*Continued from page 28A*)

in a typical broadcast station installation, and data on the control console and other accessories designed for use with either of the transmitter units. This brochure can be obtained by writing to Department 516, RCA Engineering Products Department, Camden, N. J.

Low-Resistance Ohmmeter. 12 pages with photographs, diagrams, and charts. In this booklet, James G. Biddle Company gives complete information on the various aspects of low-resistance testing, its application, and so forth. Some of the subjects include electrical maintenance tests of cable and conductor joints, oil circuit breaker assemblies, rotating equipment, transformers and coils, and test for controlling manufacturing and assembly processes. A copy of Bulletin 24–25–7 will be sent on request to James G. Biddle Company, 1316 Arch Street, Philadelphia 7, Pa.

Process Control Panels Bulletin. A wide range of applications of automatic electrical process controls that solved the problems of co-ordinating operations of feeding, weighing, conveying, mixing, and delivering, is described in this bulletin by the Richardson Scale Company. Dealing primarily with the problem and solution by automatic control of large-scale foundry operations, the bulletin also illustrates master panels, that are controlling processes in proportioning ingredients for glass, rubber tires, pharmaceuticals, distilled products, asbestos shingles, confectionery, plastics, and electrodes for production of aluminum. Copies of Bulletin 6148 are obtainable by writing to Richardson Scale Company, Clifton, N. J.

Large Induction Motors. 24-page illustrated booklet. Allis-Chalmers describes its large induction motors of the squirrel-cage, wound-rotor, bracket-bearing, and pedestal-bearing types. The bulletin also charts electrical characteristics, representative full-load power factors, and approximate range of starting torques of squirrel-cage motors larger than 200 horsepower. Strator, rotor, and bearing construction of the motors is described, along with some common special features which can be provided with mechanical modifications to suit particular applications. Copies of Bulletin 05B6232A are available upon request from Allis-Chalmers Manufacturing Company, Milwaukee 1, Wis.

Glass Products Bulletin. Glass products for signal, technical, and industrial purposes including color filters, industrial lenses, instrument covers, and sight glasses, are described in a new 24-page bulletin. Write to Kopp Glass, Inc., Swissvale, Pa., for your copy.

Construction Guide for Corrosive Fluids. Bulletin. Four pages. Recommendations on construction materials for almost 400

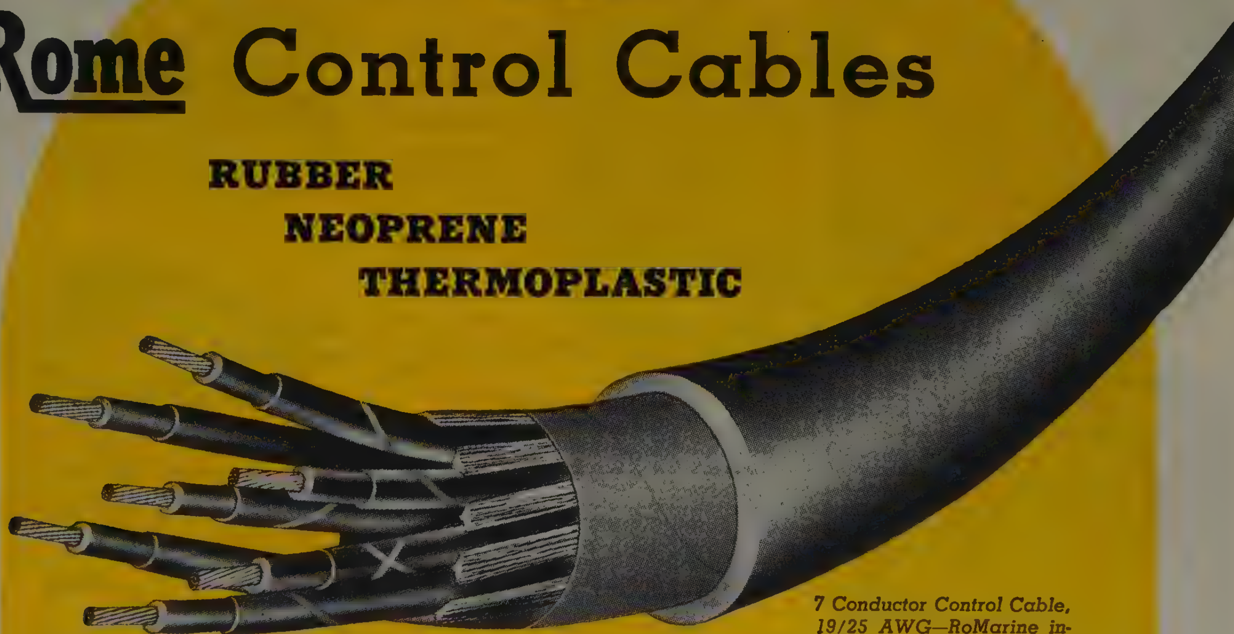
(*Continued on page 36A*)

TO ELIMINATE
CONTROL CIRCUIT FAILURE...

Specify

Rome Control Cables

RUBBER
NEOPRENE
THERMOPLASTIC



7 Conductor Control Cable, 19/25 AWG—RoMarine insulation with individual conductor sheath of Neoprene—RoPrene (Neoprene) sheath over all—600 Volts.

Protect those vital control circuits . . . the "nerve system" of your whole distribution network . . . with the dependability of Rome Control Cables. You can ill afford the loss of revenue and customer good will when outages occur from control circuit failure. As a matter of fact there is no need to run that risk. Rome Control Cables are manufactured to one standard of quality . . . the highest . . . and carry with them a sense of responsibility for dependable and unfailing service.

In Rome Control Cables, too, you will find variety of construction to meet your particular requirements. In the design of individual conductor insulation, as well as outer protective sheath, Rome Synthinol* thermoplastic, rubber, and Neoprene compounds can be combined, or used together, to provide the ultimate in service performance. Two typical Control Cable constructions are described in Specifications **CT-1** and **CRM-1.** Write for your copies today.

*TRADEMARK REGISTERED

FROM BAR TO FINISHED WIRE

ROME CABLE
CORPORATION
ROME • NEW YORK

ROME CABLE ROME, N.Y.

TRADE LITERATURE *(Continued from page 34A)*

different corrosive liquids and gases are given in this bulletin published by Fischer and Porter Company. Copies may be had by requesting bulletin number 97 from Fischer and Porter Company, Department 8M-L, Hatboro, Pa.

Metal Problems in Electric Products. A 36-page booklet published by The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y., covering special operational problems such as high temperature, corrosion, formability, abrasion, fatigue strength, magnetostriction, and many others commonly confronting the electrical engineer and designer.

NEW PRODUCTS • • •

ATR Inverters. American Television and Radio Company, 300 East Fourth Street, St. Paul 1, Minn., announces a new line of d-c—a-c inverters, operating on d-c input voltages ranging from 6 volts direct current to 220 volts direct current, delivering an output of 110 volts, 60 cycles, alternating current at output capacities ranging from 75 watts to 500 watts. These inverters are designed especially for operating a-c radios, public address systems,

(Continued on page 47A)

NEW PRODUCTS (*Continued from page 36A*)

television sets, amplifiers, small a-c motors, and electric appliances, from d-c voltage sources. Being featured in the line is an automatic switching unit for use as an auxiliary unit with 32-volt and 110-volt d-c input converters, permitting the automatic start and stop of these units as the load is turned on and off. The ATR inverter line includes more than 33 different standard types.

Automatic Oil Conditioner for Transformers. A thermosiphon oil conditioner with no moving parts which absorbs moisture, acid, and sludge from transformer oil continuously while the transformer is in operation is announced by Westinghouse Electric Corporation, Pittsburgh, Pa. Units mounted on old or new transformers maintain properties of transformer oil or Inerteen essentially the same as those of new transformer liquid dielectrics for as long as the absorbent material remains effective. When, after several years, the yearly inspection tests show oil deterioration, replacing the conditioner is all that is necessary. The conditioner is manufactured for Westinghouse by the Honan-Crane Corporation of Lebanon, Ind.

Rocker Arm Welders. A new line of standard air-operated rocker arm welders, in both 30- and 50-kva capacities and with throat depths ranging from 18 to 36 inches for each capacity, has been announced by Progressive Welder Company, 3050 East Outer Drive, Detroit 12, Mich.

Telephone-Type Relays. Series "*MTA*" telephone-type relays for a-c operation up to 220 volts 60 cycles is now ready for distribution by Potter and Brumfield Sales Company, 549 W. Washington Street, Chicago 6, Ill. The *MTA* is fitted with twin palladium contacts that will carry approximately two amperes noninductive load and is available in single or double spring stack with any contact combination up to 13 springs. The baked-varnish-impregnated coil will stand constant duty with dissipation of only 0.50 to 0.65 watt and will operate on varying line source within 18 per cent of rated voltage without hum. With the *MTA* series, rectification is no longer needed to obtain chatter-free operation. Both the *MTA* for alternating current or the *MT* for direct current meet UL and JAN specifications and are essentially shockproof or vibrationproof. Both are suited to aircraft application. The *MTA* midget relay, "smaller than your thumb," weighs $1^1/_4$ ozs, measures $1^1/_2$ inches by $1^7/_{32}$ inches by 11/16 inches.

Phase-Sequence Indicator. An indicator for the manufacturing, industrial and central station fields has been announced by the meter and instrument divisions of the General Electric Company, Schenectady 5, N. Y. Entirely static, with no moving parts, bearings, or pivots, the indicator is applicable to either 120-, 240-, or 480-volt circuits at 25, 50, and 60 cycles. Three 30-inch leads, that are an integral part of the

(*Continued on page 52A*)

(*Continued from page 46A*)

supervision military and civilian personnel, training personnel in the operation of projection equipment, inspecting and recommending improvements in buildings to provide for the safe projection of entertainment film, and other details involved in the operation of motion picture theaters. Salary, $7794 a year. Location, Japan. Y-1488.

CHIEF ENGINEER, 35–45, preferably married, mechanical or electrical graduate, with experience including gear design, basic structural engineering, hydraulics, some pneumatics, for the development and design of new products, and improvements to present ones for manufacturers of mining machinery and equipment. Salary open. Location Pennsylvania. Y-1496.

ELECTRICAL ENGINEER with seven to ten years' experience in analysis, development and test of communication equipment, radar equipment, electromechanical servo mechanisms, electronic timing and control circuits. Master's degree or equivalent study of mathematics, electronics and applied physics, capable of planning and directing a project or number of projects. Location, New York, N. Y. Y-1502.

ELECTRICAL ENGINEER, graduate, experienced in the design and installation of aircraft electrical systems and equipment, to make system studies and analyze transient conditions. Location, southern California. Y-1474.

SALES AND SERVICE ENGINEER, electrical, for manufacturer of magnetic analysis equipment for steel mills and steel fabricators. Location, Midwest. Y-1485.

TEACHING PERSONNEL. (a) Instructors to teach courses in electrical engineering. (b) Associate Professor, to teach graduate courses in communications. Should have advanced degree in electrical engineering from school specializing in communications. Location, South. Y-1430.

ELECTRICAL ENGINEER, not over 40, single, with degree in electrical engineering and experience in some phases of the generation, distribution, and usage of electric power. Any experience in hydroelectric generation desirable. Position is largely in sales and application engineering, having to do with a large variety of electrical equipment with emphasis on waterwheel generators. Training in Pennsylvania and New York, and later semi-permanent location in India. Y-1407.

ELECTRICAL ENGINEER, under 35, for design of public utility power substations of voltages 22,000 to 132,000, transformer vaults, and similar installations. Man with minimum of two years experience or test course graduate preferred. Salary open. Location, West Virginia. Y-1250.

RESEARCH AND DEVELOPMENT ENGINEERS, including research manager, physicist, mechanical, structural, electrical (electronics and communications), utilities, for civil engineering laboratory. Salary, $8000–$10,000 a year. Government work. Location, Maryland. Y-1308.

ELECTRONIC ENGINEER with an electrical degree and preferably with two to five years experience. Veteran preferred who has served as radar or communications officer. Will act as liaison with electronic devices contractors. Salary, $3700–$5200 a year. Some traveling. Location, New York, N. Y. Y-1322.

DESIGN ENGINEER, electrical graduate, with three to five years home radio receiver experience, to design and lay out various combinations of radio, phonograph and television sets. Salary, $4680–$4940 a year. Location, New York, N. Y. Y-1340.

TECHNICAL EDITORIAL WRITER, electrical 35–40, with at least ten years experience in engineering department of electrical public utility, covering generation, transmission and distribution, to make write up of utility operations. Salary, $6000–$7000 a year. Location, New York, N. Y. Y-1357(b).

LECTURER, degree in electrical engineering, with practical experience in heavy or light current electrical engineering or electronics, with some teaching experience. Will be required to give instruction, conduct examinations, and do research work. Three-year contract. Location, Australia. Y-1368.

EDITORIAL ASSISTANT, mechanical or electrical graduate, with industrial experience in power plant, refrigeration, pumping, etc., to prepare technical articles covering maintenance and operation of power plants and auxiliaries. Salary, $3600–$6000 a year. Location, New York, N. Y. Y-1509.

ELECTRICAL ENGINEER with plant engineering experience, to supervise the work of electrical draftsmen, covering application and layout of mining and material handling equipment, and power distribution. Salary open. Location, eastern Pennsylvania. Y-1513.

RESEARCH DIRECTOR, electrical engineering or physics graduate, with minimum of M.S. in nuclear physics and some biological training and experience, to take charge of laboratory specializing in use of radioactive substances in medical field. Salary, $8500 a year. Location, East. Y-1524.

ELECTRONICS TEST EQUIPMENT ENGINEERS. (a) Senior Engineer, graduate, with at least three years design of radio electronic apparatus using oscillating circuits at high radio frequencies. Will be required to make most mathematical calculations, work out circuit diagram, line up necessary components, and build first experimental model from performance specifications furnished by engineering department. Salary, $5000–$8000 a year. (b) Engineer, college graduate with one to three years in design work of electrical circuits using radio tubes; production trouble shooting or inspection experience will be considered. Under senior engineer, will be required to requisition necessary material, build up a working model, check out the feasibility of the circuit, make all necessary changes as indicated; will also have to work out simple circuits and simple mathematical calculations. Salary, $3600–$4800 a year. Location, Ohio. Y-1576-C-D.

TECHNICAL EDITOR, 30–35, mechanica lor electrical graduate, with industrial equipment manufacturing, process or application experience, to solicit from design, development and production engineers articles of interest to readers of industrial periodicals and to edit these articles before submission to editors. Salary, $4200–$5200 a year. Location, western Pennsylvania with occasional trips. Y-1535.

ELECTRICAL ENGINEER, graduate, with at least five years laboratory research experience in electrical insulation field, to make research studies, investigate performance and write reports covering insulating materials. Salary, $4200–$6000 a year. Location, northern New Jersey. Y-1550.

SALES ENGINEER, electrical graduate, with experience in the electrical wire and cable industry, to call on government and industrial firms. Location, Washington, D. C. Y-1551.

ELECTRICAL ENGINEER, young, to run tests on rectifiers. Salary dependent upon ability. Location, Connecticut. Y-1619.

WHAT ABOUT

High-Altitude Brush Principles

FOR GROUND-LEVEL ROTATING ELECTRICAL EQUIPMENT?

When Stackpole produced the first long-life brushes for high-altitude aircraft generator service, it looked as though these same unique principles of brush composition would also solve a lot of brush problems in equipment for ground level use where difficult atmospheric conditions, chemical fumes and other adverse conditions were causing trouble.

In some instances, outstanding success was achieved. In others—and it was hard then to tell exactly why—results were disappointing.

That was several years ago. Meanwhile, subsequent Stackpole developments in high-altitude brush compositions and production control methods have scored real progress in solving these more puzzling ground-level applications. In a high percentage of cases, they have resulted in materially longer brush life under adverse conditions, greatly minimized commutator wear and generally improved standards of equipment operating efficiency.

TEST OFFER! Send details of your difficult ground level applications for sample brushes. *Test them on your actual equipment under actual operating conditions.* Recent experience indicates that, in a large majority of cases you will find that these unique brushes answer your problem.

NOTE: Stackpole brushes are sold only to equipment manufacturers—not as replacements.

STACKPOLE CARBON COMPANY, St. Marys, Pa.

STACKPOLE

MOLDED CARBON, GRAPHITE AND POWDERED METAL SPECIALTIES . . . *Write for details on any type*

BATTERY CARBONS • BEARINGS • BRAZING FURNACE BOATS • BRUSHES • CARBON, GRAPHITE AND METAL CONTACTS • CARBON VOLTAGE REGULATOR DISCS • CHEMICAL CARBONS • CLUTCH RINGS • DASH POT PLUNGERS • POWER TUBE ANODES • RESISTANCE WELDING AND BRAZING TIPS • SEAL RINGS • SPECIAL MOLDS AND DIES • TROLLEY AND PANTOGRAPH SHOES • WATER HEATER & PASTEURIZATION ELECTRODES • WELDING CARBONS, ETC.

NEW PRODUCTS (*Continued from page 47A*)

instrument have insulated clips to assure quick, easy operation. The indicator can be used to predict the directional rotation of polyphase meters for machine drives, elevators, air-conditioning, and similar equipment; also to determine the proper connections for paralleling generators, transformer banks and power busses; to determine proper connections for watt-hour meters, reactive-component meters, power-factor meters, kilovolt-ampere meters, reverse-power relays, and phase-sequence relays. It also can be used to check vacuum-tube, thyratron, rectifier, and inverter installations, as well as to study vector relations of polyphase circuits. The phase-sequence indicator is housed in a leatherette-covered wooden case with a cover to protect the two types *NE-51* standard neon lamps.

Amplifier. A circuit development, known as the "transient peak" circuit is one of the features of the new 10-watt model of the Brook High Quality Amplifier. This circuit permits the amplifier to handle power peaks considerably higher than its 10-watt rating, at the same time holding distortion within the figures published by the manufacturer as applying to constant power output. Both bass and treble controls provide attenuation as well as boost and consist of two-stage resistance-capacitance networks in which equalizing curves for various types of recordings are obtained through use of eight-step selector switches. Two high impedance inputs provide high gain with equalization for magnetic-type pickups and medium gain for crystal pickups and tuners. Output impedances range from two to 500 ohms. For further information write to Brook Electronics, Inc., 34 DeHart Place, Elizabeth 2, N. J.

Fluxmeter Calibrating Unit. A new device for calibrating both the GE indicating fluxmeter and fluxmeter-type photoelectric recorder has been announced by General Electric's meter and instrument divisions. The new unit consists of an Alnico magnet rod and a housing with a built-in search coil that is tapped and connected through a selector switch and terminal post. The magnet, one end of which is painted black, is approximatey 10 inches long and 5.8 inches in diameter. To use, the unit is set upright with the unpainted end of the magnet placed in the opening atop the housing. The unit then is connected in series with the search coil to be used in making the flux measurement, and the switch is set at the desired value of flux-linkages. When the magnet is removed from the housing, the desired flux-linkage takes place. This makes it possible to calibrate the fluxmeter or recorder so that each millimeter of scale reading will be equivalent to a known value of flux-linkages. For detailed information write to the General Electric Company, Schenectady 5, N. Y.

Typee Turbine. A new all-weather general purpose turbine for driving industrial pumps, fans, blowers, compressors, paper machinery, and small generators, the Typee is offered by the Westinghouse Electric Corporation. A choice of three wheel sizes, 16, 20, and 25-inch, permits Typee turbines to be applied over a range of 5 to 1,500 horsepower with steam conditions up to 600 pounds gauge at 750 degrees Fahrenheit, and speeds of 1,000 to 7,000 rpm. Equipped with heavy duty parts the turbine will operate at 1,500 pounds gauge at 950 degrees Fahrenheit. Further information in the Typee turbine may be obtained from the Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pa.

Tube-Type Motors. A new line of tube-type totally-enclosed fan-cooled squirrel-cage motors ranging from 150 to 600 horsepower has been introduced by Allis-Chalmers. Internally, the new motor is divided into two isolated parts with each side having its own path of internal air circulation. Because of its construction, it is possible, through simple maintenance, to keep the motor free of power-destroying agents that tend to clog air passages in the conventional type of fan-cooled motors. The new line is being offered with Underwriters' labels for 1-D or 2-G locations in ratings of 3,600 rpm, 250 to 400 horsepower, 1,800 rpm, 200 to 300 horsepower, and 1,200 rpm, 150 to 200 hp. Further information may be obtained from Allis-Chalmers, Milwaukee, Wis.

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10-48